ASSESSMENT OF RADIATION DOSE IN COMPUTED TOMOGRAPHY EXAMINATION OF ADULT PATIENT IN ABUJA AND KEFFI HOSPITALS IN NIGERIA

BY

KAMBARI LADAN SABI'U
NSU/NAS/MSC/PHY/016/14/15
B.Sc. MEDICAL RADIOGRAPHY IFCS,
KINGDOM OF MOROCCO

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, DEPARTMENT OF PHYSICS, FACULTY OF NATURAL AND APPLIED SCIENCES
IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER DEGREE IN RADIATION AND MEDICAL PHYSICS OF NASARAWA STATE UNIVERSITY, KEFFI

SUPERVISOR
DR. J.K AUDU

CO-SUPERVISOR
DR. UMARU IBRAHIM

SEPTEMBER, 2017

DECLARATION

I, KAMBARI LADAN SABI'U, declared that this dissertation "Assessment of Radiation Dose in Computed Tomography Examination of Adult patients in Abuja and Keffi, Hospitals in Nigeria" has been written by me and it is a report of research work. This work has not been presented in any previous academic examination towards the attainment of any qualification in Radiation and Medical Physics. All quotations are indicated and sources of information and facts are specifically pointed and acknowledged by means of reference

KAMBARI LADAN SABI'U
NSU/NAS/MSC/PHY/016/14/15

CERTIFICATION

The dissertation "Assessment of Radiation Dose in Computed Tomography Examination of Adult patients in Abuja and Keffi, Hospitals in Nigeria" meets the regulations governing the award of Master's Degree of Science in Radiation and Medical Physics, of the school of Postgraduate Studies, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi and is approved for its contribution to knowledge.

Dr. I. Umar Date
Chairman, Supervisory Committee

Dr. A.S Aliyu Date
Member, Supervisory Committee

Dr. M.U Gurku Date
Head of Department

Prof. B.S Jatau Date
Dean, Faculty of Natural & Applied Sciences

Dr. Lucas W. Lumbi Date
Internal Examiner

Prof. E.E Ike Date
External Examiner

Prof. S.A.S Aruwa Date
Dean School of Postgraduate

DEDICATION

I dedicate this work to my late father Alh. Mal. Ladan Kambari, May the gentle soul of my Dad rest in perfect peace and may Allah (SWT) grant him the Highest Part of Aljannah (Paradise) Ameen.

ACKNOWLEDGMENT

All praises are the due to Almighty God lord of the worlds, who gives strength and wisdom through out the period of this research work. I would like to express my sincere gratitude to my able supervisors Dr. Joshua K sAudu and Dr. Umar Ibrahim for their guidance, encouragement and constructive and positive criticisms and for spending their golden time in going through this work. Their pieces of advice and correction have helped me immensely in making this work a great success.

My thanks and appreciation are also extended to all the staff of Physics Department, Nasarawa State University, Keffi, Nigeria. May the Almighty God reward them abundantly.

I really appreciate the contribution and effort of a great elder brother Auditor Suleiman Ladan Kambari, Audit Unit Department, Nasarawa State University, Keffi, Nigeria. Your selfless advice and guidance have helped in making this work a reality.

I would also like to extend my gratitude to my colleagues (Radiographers) in Radiology department, FMC Keffi, Nasarawa State, Nigeria especially Radiographer. Ubi Nkanu Eyong for their advice and contribution throughout the period of this work.

Special thanks goes to Dr. Mustafa Babakolobe, former HOD Radiology Department, National Hospital Abuja, FCT, Nigeria and the present HOD Dr. Kamaluddeen Jimoh and the resident Doctors like Dr. Nwafor Aaron and Dr. Akande Ezekiel for their contributions towards the actualization of this work.

I also gratefully acknowledge the Chief Radiographer and the entire radiographers in particular Radiographer Dike Uche of National Hospital Abuja for their assistance in the data collection processes and the ethical committee of all that participated in the Hospital for allowing the research to proceed.

I also wish to appreciate and thank the HOD Radiology department and the radiographers in particular the Radiographer Efayemi Peter of Radiography department Garki General Hospital, Abuja, Nigeria for their contribution to the realization of this work.

I am highly grateful to all members of my family most especially my lovely father Alh. Mal. Ladan Kambari and my mother Habiba Alh. Matai and my step mothers Hajiya Bakuwa Umar for their prayers, love and support through my entire life and education till datae. May Allah bless you with the reward he gives to lovely and caring parents.

My gratitude moves to my brother and sisters; Mr. Salisu Ladan K, Rabiu Ladan K., Hamisu Ladan K., Hajiya Bakuwa Mal. Tanimu, Rahmatu Ladan K. and all other not mentioned for their support and prayers; without you this journey would not have been successful.

I also acknowledge Ustaz Awwal Abdulrazak, Coordinator Al-Iman School Lafia for his contribution to my academic life.

Finally, my gratitude goes to my lovely friends who are so many to be mentioned especially Awalu Ladan Kambari. Thank you all for your support.

My special thanks go to my lovely wife Fatima Abdullahi Sulaiman and my children Anwar, Ummulsulaim and Ummu-Romman for their prayers, patience and support to the final stage of this work.

TABLE OF CONTENT

CHAPTER ONE
INTRODUCTION

CHAPTER TWO
LITERATURE REVIEW

CHAPTER THREE
MATERIALS AND METHODS

CHAPTER FOUR
RESULTS

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

ABSTRACT

Assessment of Radiation dose in computed tomography examination of Adult patient in Abuja and Keffi, Hospitals in Nigerian was carried out. The three study centers are, National hospital Abuja, Garki hospital and federal Medical Centre Keffi, Nasarawa State. CT scan is considered to be the first investigative modality of choice for patient with severe head, chest and abdominal injuries. For us to achieve this, professionals must adhere to the principles of justification of practice and optimization of radiation protection. Dose report and scan parameters for head, chest and abdomen were assessed during seven months period at the three study centres. Ethical approval were obtained from the study centers. Data on CT Dose index (CTDIw) and dose length product (DLP) available and achieved on CT scanner control console was recorded for a minimum of 10 average sized patients for each facility to established a local Diagnostic reference level (LDRLs) and radiation dose optimization Data were collected, using a purposive sampling technique, from 131 adult patients weighing 70±3kg) from Philip brilliance, Toshiba Alexion and General Electric (GE) CT scanners for the study. The collected data were analyzed using SPPSS version (20) statistical software. Third quartile values of the estimated LDRLs for CTDIw and DLP were determined as (49.8mGy and 9639mGy) and (10.9mGy and 432.8mCy*cm) and (12.7mGy and 560mGy*cm) for head, chest and abdominal CT scan, respectively. This study has established local diagnostic reference levels (LDRLs). And the CTDIw obtained are almost relatively higher to the reported data from the European Commission (Head: 10mGy, Chest: 10mGy and Abdomen 12.7mGy). The DLP are comparably lower than all the reported value from the European commission (Head:1000mGy, Chest:600mGy and Abdomen: 800mGy). CT dose optimization is recommended.

CHAPTER ONE
INTRODUCTION

1.2 Background of the Study

Computed Tomography (CT) is the largest source of exposure to ionizing radiation in medicine, contributing approximately 30% of the radiation dose to the population in the United States. In 2010 an estimated note 80 million CT scans were performed, with the use of CT increasing (Milwauke & Wisconsine, May 2012). This is due in part to the larger head, chest, abdominal and areas to be covered in the examination as well as the presence of many radiation sensitive tissue or organs. Additionally, a routine CT examination normally involves pre- and post- contrast media series which increases the irradiated volume by a factor of more than one (European Commission, EC 1998; Web *et al.*, 1999).

Computed tomography (CT) was introduced into clinical practice in 1972 and had revolutionized x-ray image by providing high quality images which reproduced transverse cross sections of the (European commission, 2014). The technique offered improved low contrast resolution for better visualization of soft tissue, with relatively high in absorbed radiation dose. The initial potential of the imaging modality has been realized by paid technological developments, resulting in the continuing expansion of CT practices. As a result, the numbers of examinations are increasing; to the extent that CT has made a substantial impact on not only patients care but also patients and population exposure from medical x-rays. Today, it accounts for up to 40% of the resultant collective does from diagnostic radiology in some countries of the European Union (EU). Special measures are consequently required to ensure optimization of performance in CT, and of parent's protection (European commission, 2014).

It was established that more than 65 million CT scans per year are currently obtained in the united state (Brenner & Hall, 2007). By nature, CT involves larger radiation does than more common conventional x-ray imaging procures.

However, CT is associated with relatively high radiation does, with a corresponding increased risk of carcinogenesis (Foley *et al.*, 2012). Therefore, rational use of the modality requires strict adherence to the tenets of radiation protection-justification, optimization and minimization to ensure that the risk to patients does not outweigh the benefit gained from the technique (Australian commission, 2008). At the core of optimization is the establishment of diagnostic reference levels (DRLs) (European commission, 1999) first purposed by the international commission on radiation protection (ICRP) in 1996 and subsequently introduced into European and Irish legislation. DRLs allow the identification of abnormally high dose levels by setting an upper threshold, which standard does levels should not exceed when good practice is applied. Excessive does in CT are not as readily identified through image quality affects, as in standard firm-based radiography (Foley & Mcentee 2012). Thus, an awareness of typical does levels allows CT users to quickly identify and address any protocol which do not meet the ALARA (as low as reasonably achieve) principle, thus improving radiographic practice. Currently in Ireland, over 200 000 CT scans are performed on annual basis, and this number is growing steadily. The ICRP also recommends that DRLS should be based on relevant local, regional or national data (Europeans commission, 1999). CT procedure is one of the fastest and most accurate tool for examining the head, chest, abdomen and pelvis because it provides detailed and cross-sectional views of all types of tissue (Garba, 2014). CT examination should be perform only for a valid medical reason and with the minimum exposed that provide the image quality necessary for adequate diagnostic information. Over the past 30 years, development in CT technology have been continuous, providing faster superior quality images, better diagnostic information thus, opening new potentials for clinical applications (Geleijst *et al.*, 2013). It was estimated that in 1989 in the UK depite constituting only 2% of all requested radiological examinations, CT contributed up to 20 % of the collective dose. In 1998, that is 10 years later, the use of CT increased to 5% of all radiological examinations, there by contributing up to 40% of the collective dose (Shrimpton & Hillier, 2014). In Germany, CT represents 2-5% of all radiological examinations, contributing p to 33% of the collective dose. In 2006 in the USA, CT comprised of 59% (67 million CT exams) of all diagnostic imaging examinations utilizing ionizing radiation. Word wife, CT constitutes up to 5% of radiological examinations yet contributes about 34% of the collective dose (McEntee & Rainford, 2012).

Periodic national review and surveys concerning frequency and dose for medical x-ray procedures in the UK, conducted over the last 35 years by public health England (PHE) and previously by the national radiological protection board (NRPB, 2005) and the health protection agency (HPA, 2013), have provided unique insight into the national trends in population exposure (Shrimpton, 2014). These surveys have also formed the basis for setting local reference dose as a quality improvement tool in the promotion of the optimization of patient's protection. Such dose data is similar in purpose to national diagnostic reference levels, DRLs. (ICRP, 1996; 2007). Legislating and guidance issuing bodies such as International commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and European Union have been active in this area and have developed the idea of "Diagnostic".

Reference Levels (DRLs). The context of the international and national situation on the idea of DRL's is reasonably understandable.

The two basic principles of radiation protection for medical exposure as recommended by ICRP are justification of practice and optimization of protection, including the consideration of diagnostic reference levels. The emphasis is to keep does to the patient as low as reasonably achievable (ALARA), consistent with clinical requirement.

Justification is the first step in radiation protection and no diagnosis is justifiable without a valid clinical indication. Every examination must result in a net benefit for the patient. Justification for CT also implies that, the required result cannot be archived by other methods which are associated with lower risk for the patient. Ultrasound and MRI offer alternative to CT in many areas of application.

In respect of radiological examination, ICRP draws attention to the use of diagnostic reference levels as an aid to optimization of protection in medical exposure. Once the diagnostic examination has been clinically justified, the subsequent imaging process must be optimized. The optimal use of ionizing radiation involves the interplay of three important aspects of the imaging process: diagnostic quality of the image, radiation dose to the patient and choice of examination technique.

The optimization of patient protection in computed tomography requires the application of examination-specific scan protocols tailored to patient age or size, region of imaging and clinical indication in order to ensure that the dose to each patient is as low as reasonably achievable for the technical purpose of the CT examination (Mundi *et al.*, 2015).

1.2 Statement of the Problem

CT examinations have been described as a high radiation dose procedure, and the CT head, chest and abdomen, are the most common examination in radiology department in most countries. Diagnostic reference level helps to identify situation where unnecessary radiation dose is used for diagnosis. As such, it has been recommended by the international organization such as International Atomic Energy Agency that every country should establish their dose reference level. However, in Nigeria there is no national dose reference level established for CT procedure.

Therefore, this study intends to start with local dose reference level with a view to establish national DRLs in future for Nigeria.

1.3 Research Question

Research question is thus, what is the estimated mean and third quartile values of $CTDI_w$ and DLP received by a patient undergoing Head, Abdomen and chest CT in Nigeria.

1.4 Aim of the Study

The aim of the study is to perform a CT Dose Assessment or survey in three Nigerian hospitals, National Hospital Abuja and Garki Hospital, Federal Capital Territory Abuja and Federal Medical Center Keffi with intent on establishing a local diagnostic reference level (LDRL).

1.5 Study Objectives

The objectives of this study are to:

i. Perform a CT dose assessment in three Nigerian hospitals, National Hospital Abuja and Garki Hospital, Federal Capital Territory Abuja and Federal Medical Center Keffi by acquiring data from CT unit located in the three study centres.

ii. Study the variation of dose descriptors weight CT Dose index ($CTDI_W$), Volume CT Dose index ($CTDI_{VOL}$), Dose length product (DLP) and effective Dose (E) between CT scanner centers

iii. Determine the causes of the radiation doses variation in CT procedure.

iv. Find the correlations between main examination parameters chosen values in each series of and examination.

v. Compare the difference of dose descriptors values CTDIW, DLP and E, in National Hospital and Garki Hospital and F.M.C Keffi.

vi. Compare a local dose reference level obtained with established DRLs in the literature.

1.6 Significance of the Study

This study has established LDRL values that can be used in formulating national DRLs with which individual hospitals may compare their doses, for the purpose of dose optimization in CT scan of the head, chest and abdomen. The DRL has proven to be an excellent method of optimizing the medical x-ray practices in several countries (Edmonds, 2009). The establishment of DRL requires data from the medical x-ray practices been compared to the standard values. Because there is no study reported on the variation of dose descriptors weighted CT dose index ($CTDI_w$) volume.

CT dose index ($CTDI_{vol}$), dose length product (DLP) and effective dose (E) between CT scanning centers in Nigeria, as while as the comparison of the differences between dose descriptors values $CTDI_w$, DLP and E in Nigeria to those in the European countries. So it is essential to begin with a natural study in order to provide comprehensive data of head, chest and abdominal CT dose in Nigeria.

The result is a useful review of the patient's dose assessment in CT examination in some Nigeria hospitals, which will aid CT radiographer, radiologist and radiology safety officers to determine whether the radiation dose given to patient is within the standard of local practices or not.

Other countries have already started establishing DLP, $CTDI_w$, E dose and DRLs for more complicated CT procedures such as for pediatrics , coronary angiography and CT fluoroscopy. This study will initiate the process of the Nigeria and will provide measurement for radiation dose for CT examination of the head, chest, Abdomen in Nigeria hospital. This study will also contribute to staff awareness with regards to patients' dose in medical imaging.

Furthermore, the radiation control unit may be encouraged to focus in developing DRLs for all countries procedure in future.

1.7 Scope of the Study

This study was conducted in three (3) hospitals in Keffi and Abuja, Nigeria.

CHAPTER TWO
LITERATURE REVIEW

2.1 Principles of Computed Tomography

X-ray computed Tomography (CT) is a non-invasive method of acquiring the images of the inside of the human body without superimposition of distinct anatomical structures from a mathematical reconstruction of x-ray alternation measurements made through a thin axial slice of the patient (Yates, Pike & Goldenstone, 2004; Buzug, 2008).

In the other way, the CT scanner is a device using an x-ray source which can be used to give precise information on the alternation properties of thin section volume of the body. The configuration and image production are found extensively in this literature (Goldman & Felwikes, 1995; Hendee & Ritnour, 2002; Kalender, 2000; Saeram, 2000).

The CT scanner contained the following basic elements which include x-ray tube and the detector array located in the gantry and known as the data acquisition system, the image processing system and the image display system. The x-ray tube rotates around the patient producing a tightly collimated x-ray radiation photon beam. Once attenuated by the patient, the attenuated beam strikes the detector which converts the photon intensity to a digital signal; multiple profiles of patient attenuation will be collected.

2.2 Historical Development of CT System

2.2.1 Generation of CT Scanners

Computed Tomography (CT) scanners have gone through a series of improvements since introduction of first CT scanner which was produced in 1970 by Sir Godfrey Hounsfield and made available in the year1972. Since then, there has been remarkable improvement of the scanner from generation to generation of CT scanner, and was first produced in the year 1998 (Abdullah, 2009) at a time (sequential scanning).

However, during the 1980s significant advancements in technology heralded the development slip ring technology, which enable the x-ray tube to rotate continuously in one direction around patients. This contributed to the development of helical or spiral CT (Sereram, 2009). The next generation of CT scanners is now commercially available. These multi-slice or multi-detector machines utilize the principle of helical scanner but will portrait multiple rows of detector rings. They can therefore acquire multiple slices per tube rotation, thereby increasing the area of patient that can be covered in a given time by the x-ray beam (Seeram, 2009).

New advancement of the CT has also led to great increase in radiation dose to the patient (Abdullahi, 2009). The used of multi-slice computed tomography (MSCT) has aggravated the scenario with increasing collective dose of CT examination. This is because the MSCT produces higher doses to the patients compares to a single slice CT (SSCT), due to its increased capability (Abdullahi,2009).

2.2.2 Generation of CT scanner In Nigeria

In Nigeria, the initial scanner installed was a 3rd generation CT machines, but it is no longer in use. With technological advancement most of the centers have upgraded to sixth generation CT scanners which are mostly 16-sliced. Therefore, the scanners involved in this study are also of the sixth generation type.

The following sections introduced the generation of CT scanners as they are directly linked to the increased dose base on their technological advancement and clinical application level and (Lewis & Edyvean, 2005).

First generation CT scanner

First Generation of CT scanner was commercially developed in 1970s and it had the following features; rotate-translation system, single pencil beam, single detector, together translate through 180 steps and then rotate 1^0 at a time. It took 3.5 mm to produce a slice (Cunningham & Judy, 2000).

The acquisition of numerous projections and the multiple rays for projection required that single detector for each CT slice is physically moved throughout all the necessary positions. This system used parallel ray geometry. The pencil beam allowed very efficient scattered reduction, because the scatter that deflected away from the pencil ray was not measured by a detector. With regard to scatter rejection, the pencil beam geometry used was the best.

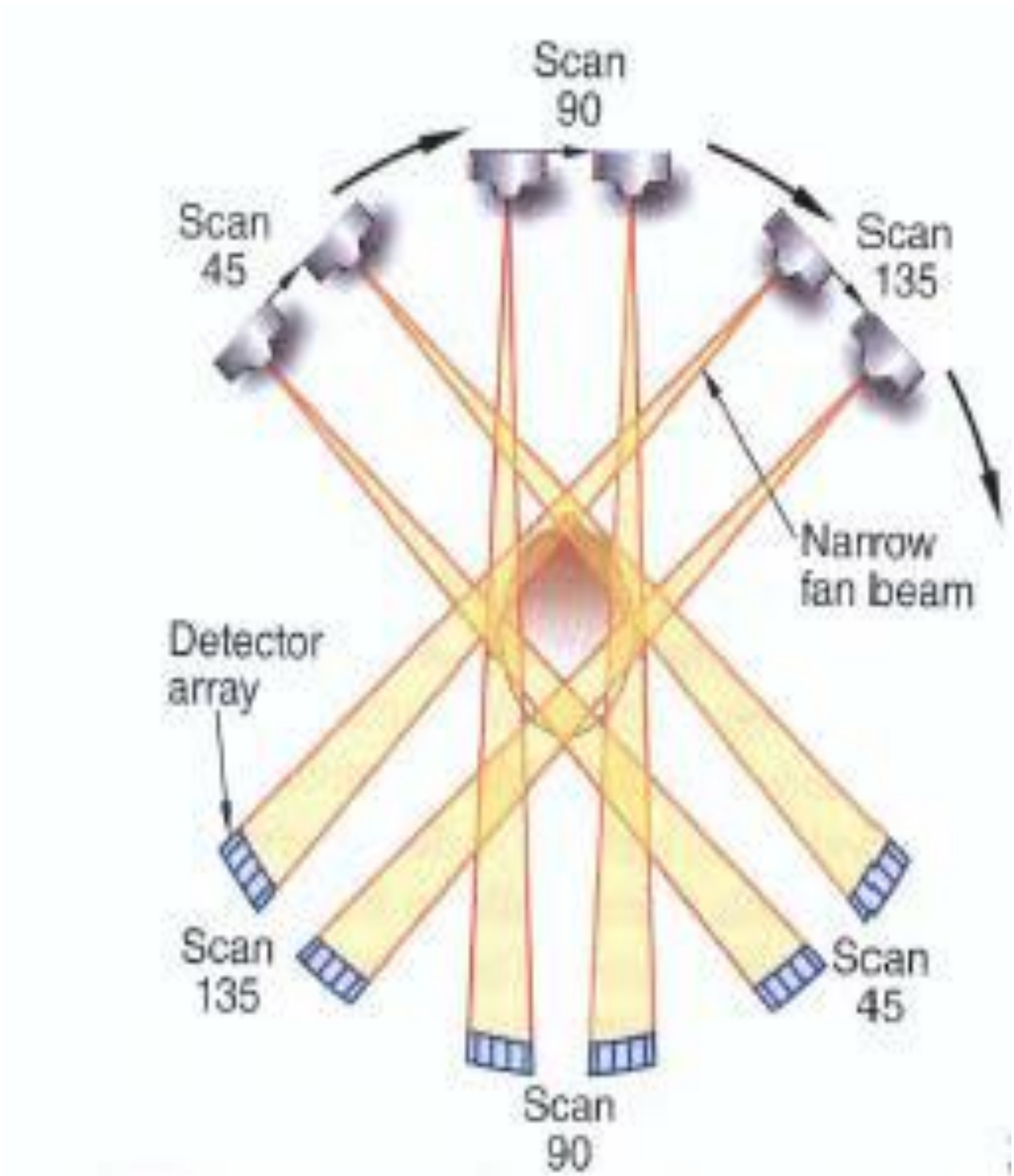

Plate 2.1: *First generation CT scanner (*Carlton &Adler, 2013)

Second Generation CT scanner

The second generation CT scanner was introduced 1977, and processed the following feature; rotate-translate system, narrow fan beam, small curved array of detectors and scan time of 30sec/slice (Cunningham & Judy, 2000).

The CT scanner of this generation was the incorporation of a linear array of 30 detectors. This increase the utilization of the x-ray beam by 30 times. Compared with single detector used per slice in first generation system. A relatively narrow fan angle of 10 degrees was used; in principle a reduction in scan time of about 30 fold could be expected. The array of the detectors, instead of just two, required the use of a narrow fan beam of radiation that allow more scattered radiation to be detected than was the case with the pencil beam used in first generation.

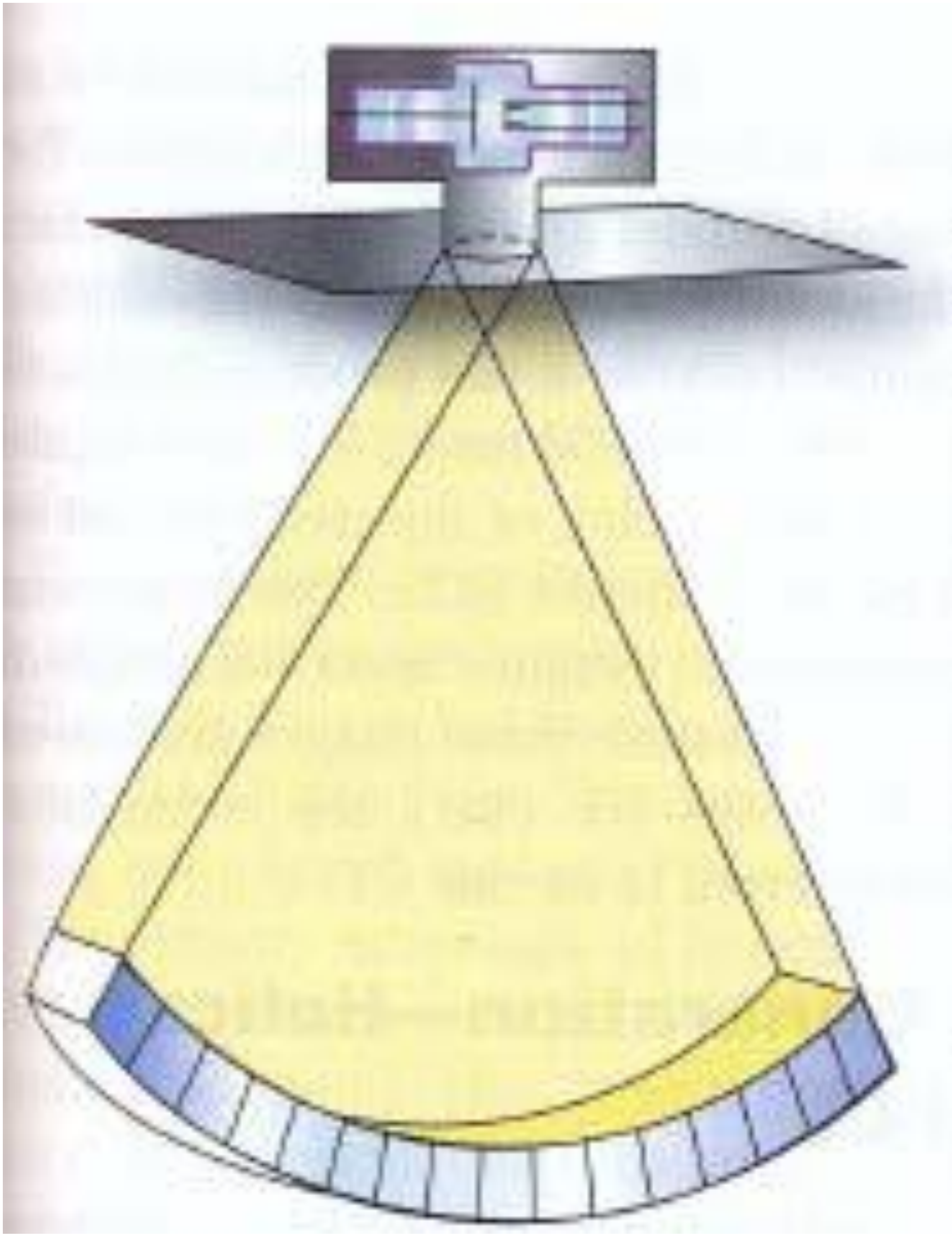

Plate 2.2: *Second generation CT scanner (*Carlton &Adler, 2013)

Third Generation CT scanner

The third generation comes into existence in the year 1976. Its main features were: rotate-rotate system, wide fan beam, larger curvilinear array of hundreds of detectors, and reduced scan time of 2 sec/slice. The tube and detectors are always in the scan geometry thus, allowing better pre-detector collimation, but making the image susceptible to ring artifacts. The third generation scanner is the most commonly used. (Cunningham & Judy, 2000). This was the type of scanner that was installed at the study site and is the scanner that was first installed before the advent of multi-slice scanners.

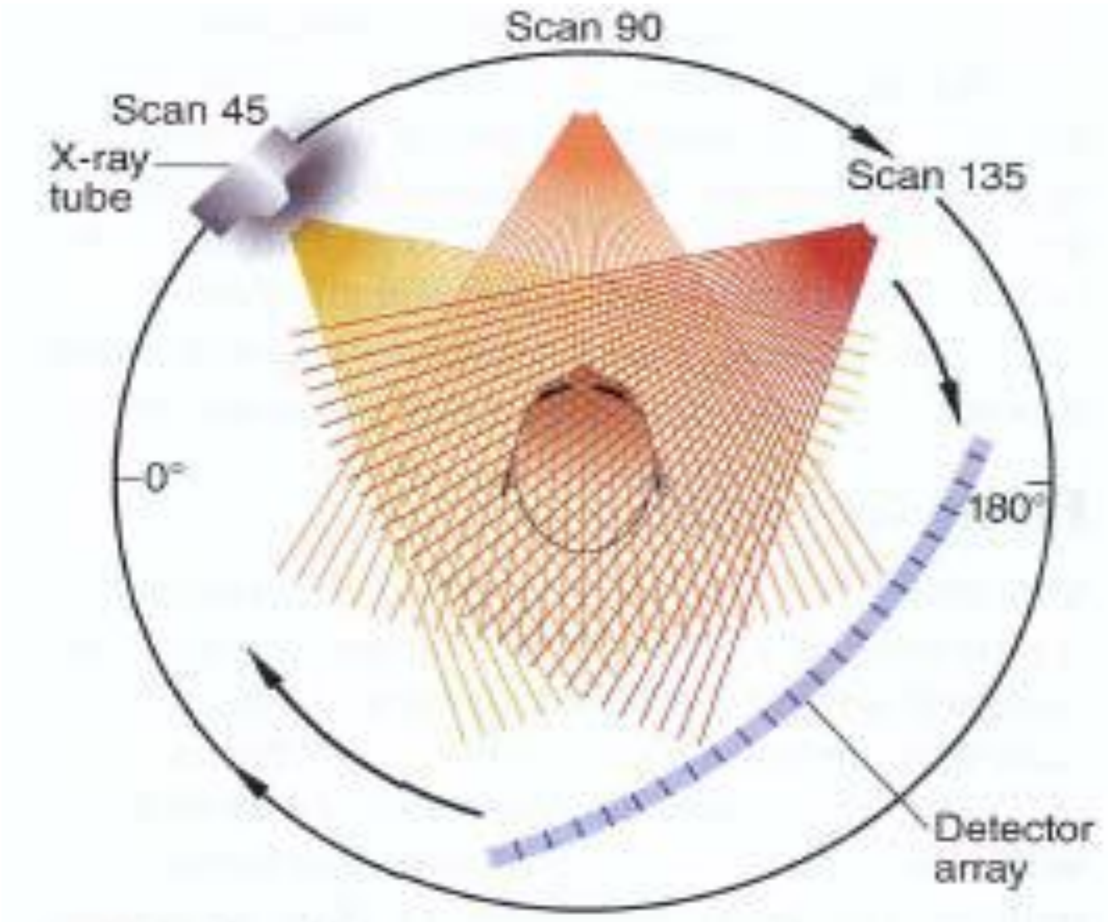

Plate 2.3: *Third Generation (* Carlton & Adler, 2013)

Fourth Generation

The fourth generation CT scanner was introduced the same year as the third generation scanners however, the feature were slightly different. The features included; rotate - Fixed system i.e. only the rotates through 360^0 around the patient. The units had wide fan beam, with a continuous ring of thousands of detectors. The main advantage over the third generation units was that ring artifacts were avoided. The tube however, was closer to the patient which resulted in an increased in radiation dose to patients (Cunningham & Judy, 2000).

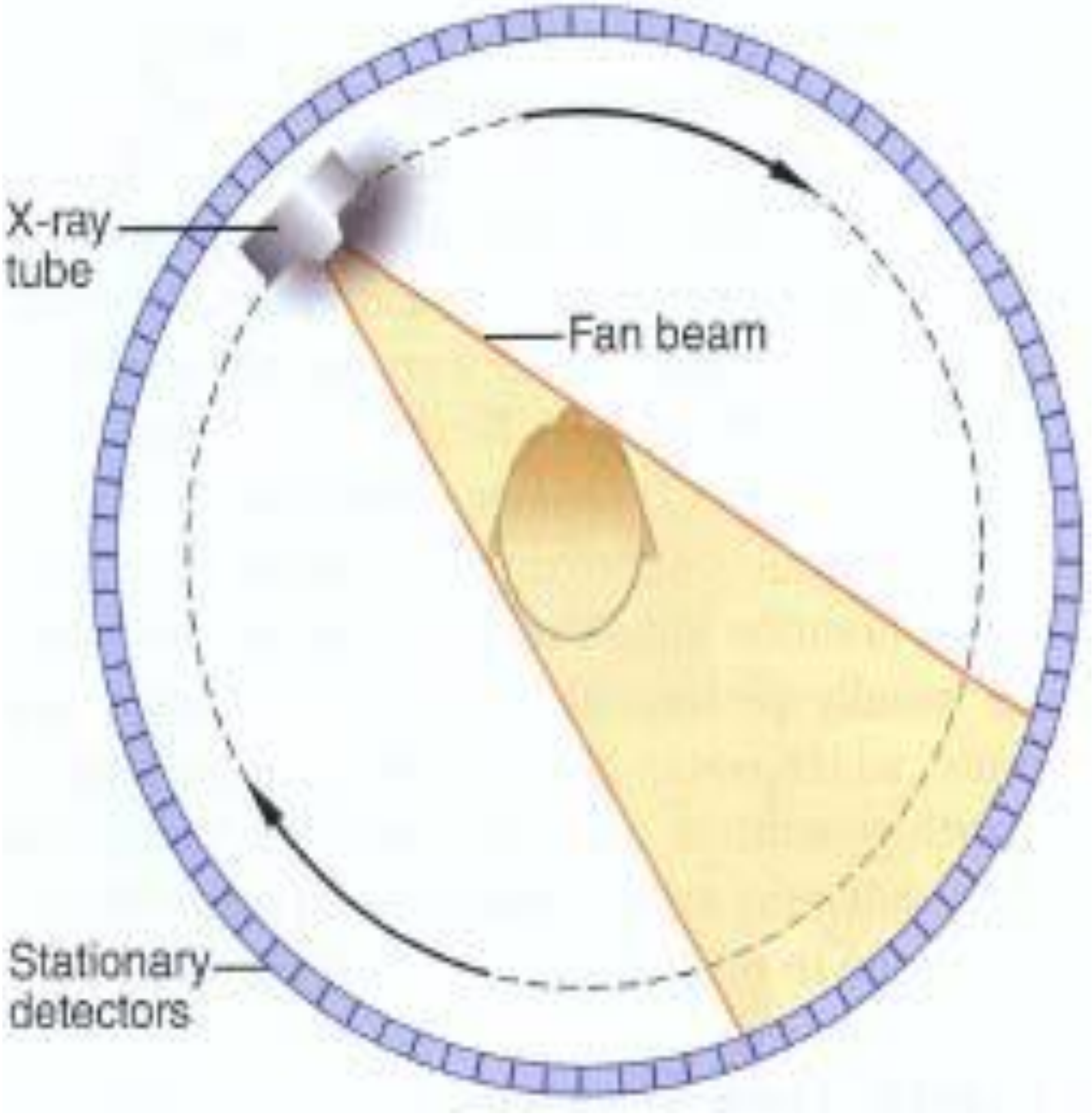

Plate 2.4*: Fourth Generation CT (*(Carton & Adler, 2013)

Fifth Generation CT scanner

The fifth generation CT scanner was introduced in 1984. Two scanners were introduced, namely; the Electron beam CT and the Dynamic spatial reconstruction scanners. They are unique in construction because they have no moving parts, a stationary x-key tube and detector. Projection data can be acquired in appropriately 50 ms which is excellent for cardiac imaging (Seeram, 2009).

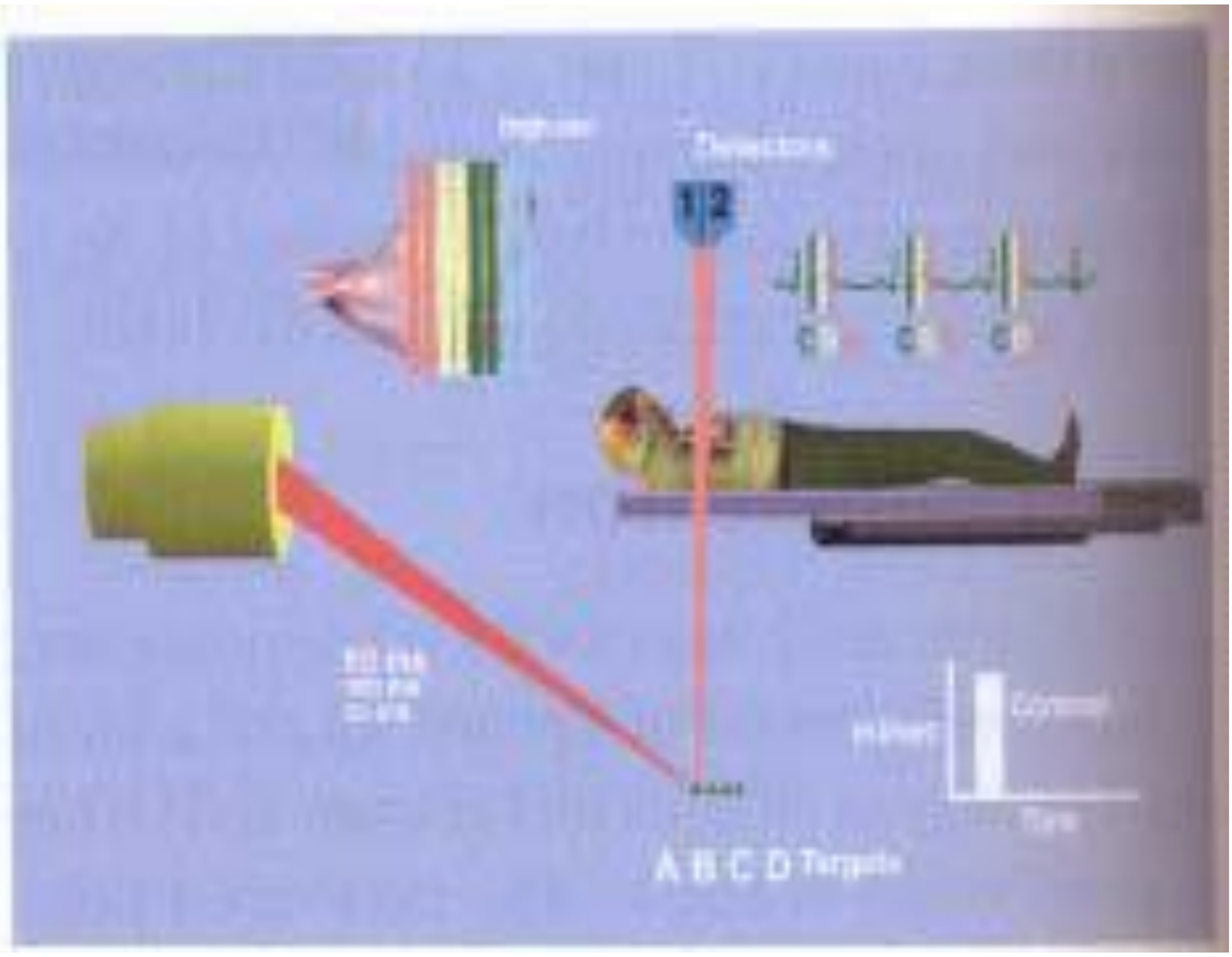

Plate 2.5*: Fifth Generation CT Scanner* (Carlton &Adler, 2013)

Sixth Generation CT scanner

Sixth generation CT scanner was developed in 1990. The scanner possessed the following features; slip ring device produced by Kolender that allows continuous rotation of the x-ray tube as the table traverses through the gantry tracing the beam geometry in the form of spiral or helical pattern (Buzug, 2008). The sixth generation scanner is what is found at the research site, and employed for study.

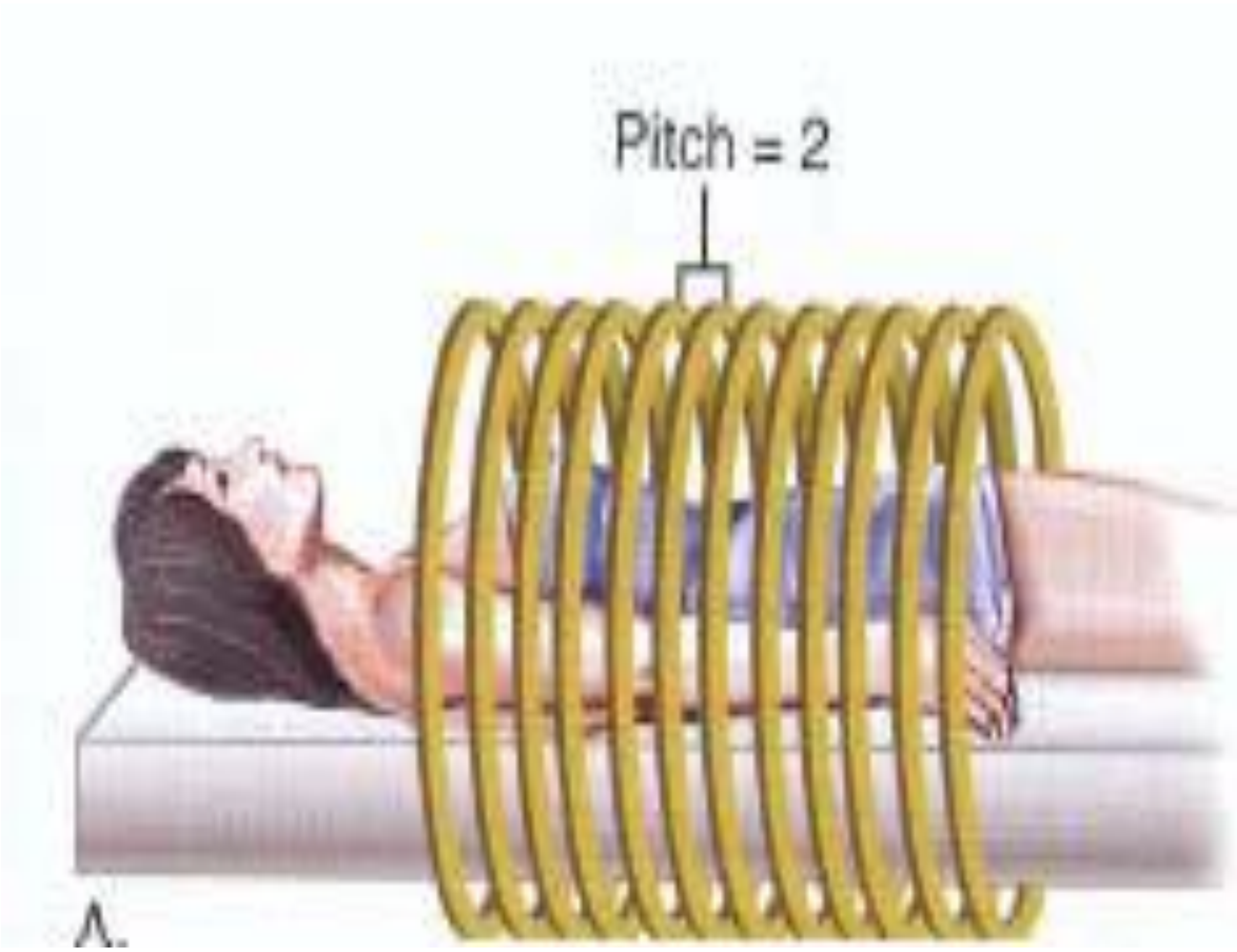

***Plate 2.6**: Sixth Generation CT* **(**Carlton & Adler, 2013)

Seventh Generation CT Scanners: Multiple detector arrays

Multiple detector arrays are used for the collimator spacing is wider and therefore, more of the x-ray that are produced by x-ray tube are used in producing image data, with conventional, single detector array scanners, opening up thickness, which is good for improving the utilization of the x-ray beam but reduces spatial resolution in the slice thickness dimension. With the introduction of multiple detector arrays, the slice thickness is determine by the detector size and not by the collimator. This represent a major shift in CT technology. This generation scanner uses a flat panel detector similar to that used in digital radiography.

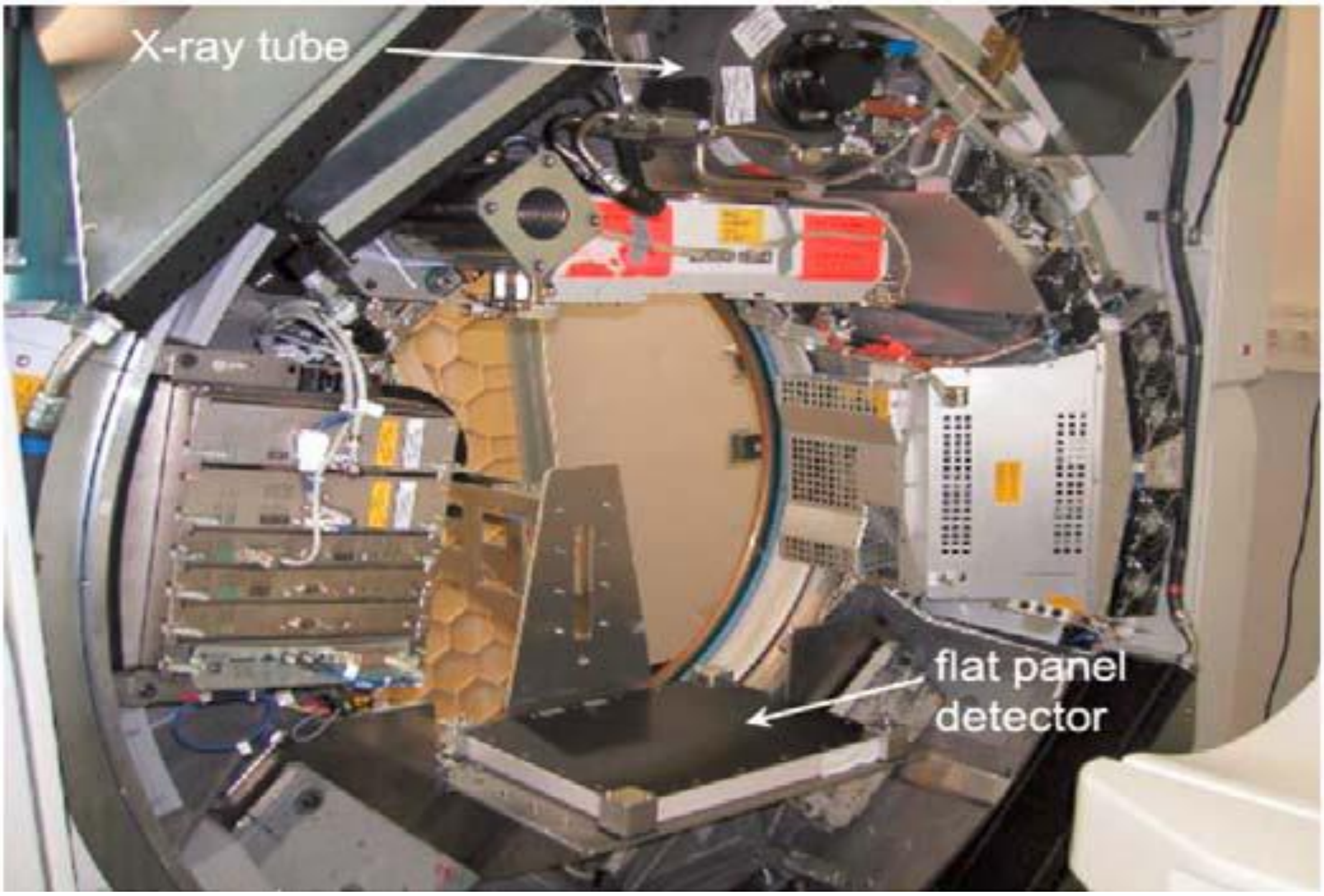

***Plate 2.7**:* **Prototype of seventh generation CT scanner** (Seeram, 2009).

Multiple Slice CT Scanners

The multi-slice CT scanner was introduced in 1991 (Buzug, 2008). This scanner is capable of producing more than one image per tube rotation. The difference between the MS CT and SS CT is that it has multiple rows of detectors (Abdullah, 2009). The latest MS CT is capable of producing up to 320 slices per tube rotation (Seeram, 2009).

2.2.3 Latest Development in CT Technology Dual Source CT

The dual source CT scanner was introduced in 2006 by the Siemens Company. The scanner has two x-ray sources and two curved detectors. In addition, it possessed the following features as: increased temporal resolution, double speed, while lowering dose even further (Seeram, 2009).

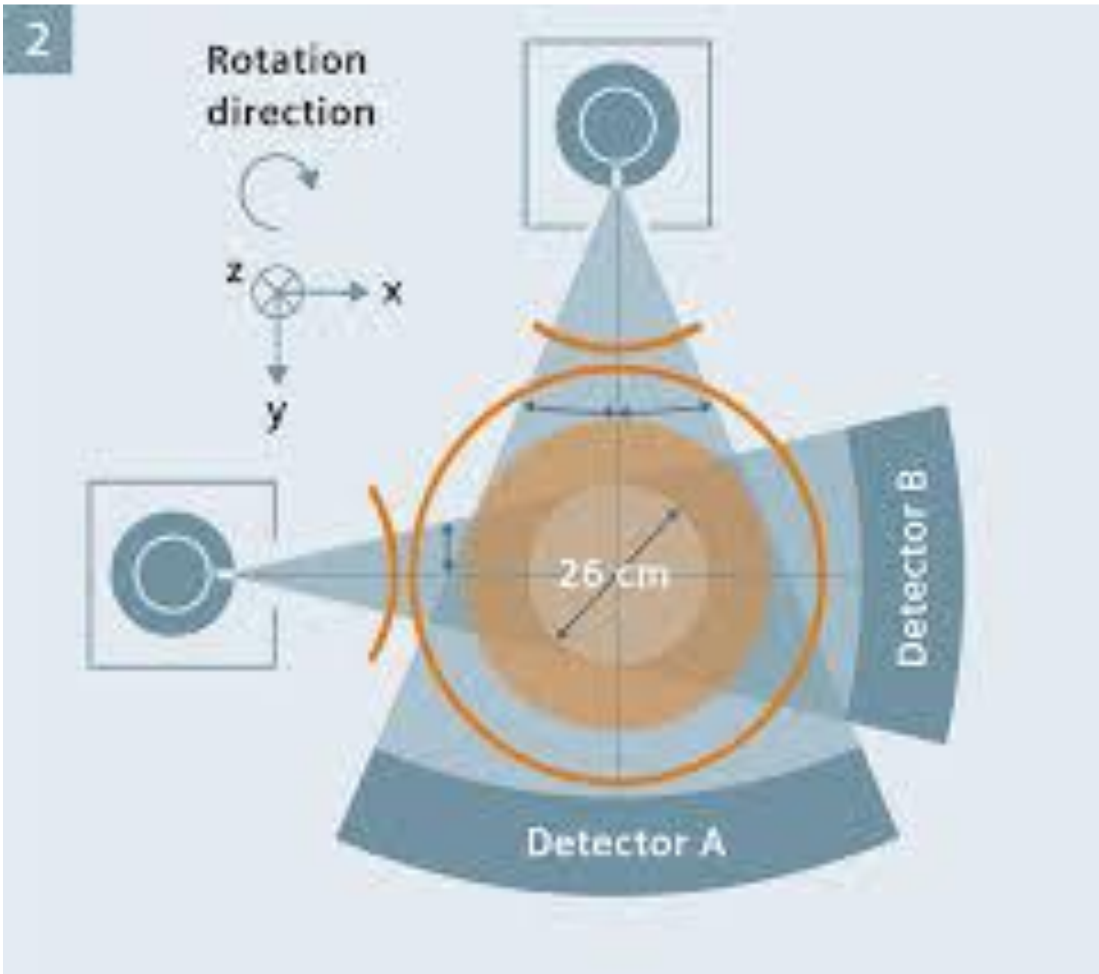

Plate 2.8: **Schematic Diagram of DSCT** (Seeram, 2009).

2.2.4 PET CT Scanner

The PET CT scanner combines two imaging modulations namely the CT Scanner and the Positron Emission Tomography (PET) Scanners. The PET Scanners show metabolism and uptake of radiopharmaceutical as hot spots, while the CT shows detailed anatomy. The combination of CT and PET give the best image quality required for diagnosis (Buzug, 2008).

Table (2.1) gives a summarized description of common generation of CT scanners as described by various authors (Subbarao, *et al.*, 1979; Cunningham, 2000; Karthikeyan & Chegin, 2005; Bzug, 2008; Abdullah 2009; Seeram, 2009).

***Plate* 2.9:** Pet CT scanner (Carlton &Adler, 2013)

Table 1.1 Generations of CT Scanners

Generation	Year Introduced	Number of Detectors	Scan time	Type of Movement	Degree of Rotation of the Tube	Beam Dimension
First	1970	Single detector	3-5 min/slice	Translate-Rotate	1^0 at a time together translate through 180^0	Pencil beam
Second	1972	Curved array of more than 30 detectors	30sec/slice	Translate-Rotate	Rotate through 180^0	Fan beam
Third	1976	Large curvilinear row of hundred of detectors	1sec/slice	Rotate-Rotate	Rotate through 360^0	Wider fan beam
Fourth	1976	Ring of thousand detectors	1sec/slice	Rotate-Rotate	Rotate through 360^0	Wider fan beam
Fifth	1984	Hundred curved detectors	Milisec/slice	No moving port	No rotation	Wider fan beam
Sixth (Spiral Scanner)	1990	Hundred curved detectors	Sub-second	Rotate-Rotate	Rotates through 360^0 or 90^0 for dual source CT scanner	Wider fan beam
Seventh	1998/2001	Flat panel detector	Sub-second	Rotate-Rotate	360^0 angle of rotation	Cone beam

(Seeram, 2009).

2.3 Background to Radiation Protection

The section introduces radiation protection in diagnosis radiology and the likely radiation injury and individual may suffer as a result of exposure to ionizing radiation.

Therefore, CT Scan being a high dose modality, it is imperative to have a better understanding of this topic so as to put measures in place for adequate protection of patients undergoing CT procedures.

2.3.1 Effect of Ionizing Radiation on Human Tissues.

Radiation injury is an individual suffers as a result of exposure to ionizing radiation. The injury is classified into two groups namely the stochastic and deterministic radiation injuries (Bushong, 2005).

2.3.2 Stochastic Effects of Radiation

Stochastic effect occurs at low dose of radiation. These effects are called non-deterministic or probabilistic effect or radiation. Principally, late effects of low-dose of radiation occurring over a long period consist of radiation –induced malignancy and genetic effects late effects include the followings: Carcinogenesis, non-specific life shortening and genetic effect. These radiation effect have a linear non-threshold dose response relationship of radiation.

2.3.3 Deterministic Effects of Radiation

Deterministic effects of radiation occur of high dose of radiation. Different organs of different radiation dose levels are affected. Therefore, there is a threshold dose below which affects are not seen. Above the threshold the probability and the severity increases. In some deterministic effects, death occurs within days or weeks. Acute effect include:

hematologic syndrome, gastrointestinal syndrome and central nervous system syndrome (CNS) (Bushong, 2008).

2.3.4 Radiation Protection

Radiation protection is concerned with prevention of stochastic and deterministic effect by setting dose equivalent limit, well below threshold values for these effects, such that the limit can not be reached even for the total period of one working life. This will reduced the risk of stochastic disease to a frequency not greater than the risk of non-radiation workers (Bushong, 2008).

2.3.5 Radiation Dosimetry

In this section methods of radiation measurement are discussed with emphasis on CT dose measurement.

Radiation dosimetry is a method of measuring radiation dose. A dosimeter is a device use to measure external radiation sources. Thermohunescence dosimeter (TLD) was the most common dosimeter used to measure dose (University of California Santa Cruz, 2000). In CT, the dose parameter used is known as CTDI measured in May. The dose cab be measure in air or in a phantom using ionization chamber or TLDS (Aweda, 2007; IAEA, 2007).

2.3.6 CT Dosimetry

Radiation dose and image quantity in CT have been a concern since the introduction of the first CT scanners in clinical practice. This is because CT is a relatively high dose procedure that contributes disproportionately to the overall radiation dose from radio-logic sources (Seeram, 2009).

In conventional radiography most of the radiation dose is received at the skin level. Therefore, a parameter known as the Entrance Skin Dose (ESD) is used to determine the amount of radiation absorbed by irradiated body. In the case of CT, the situation is different in the sense that, the dose at the periphery and at the center of the traversed tissue is more or less the same unlike in conventional radiography. This is because the beam is heavily filtered as its exist the tube, and the exposure comes from different directions as opposed to conventional radiography thus necessitating the use of a different approach such as the use of CT Dose index (CTDI) and Dose length product (DHP) to estimate the patient dose (Seeram, 2009).

2.3.7 Concept of CT Dosimetry

CT Dosimetry remains an important concept for Radiographers and Radiologist based on the following reasons; Radiographers and Radiologist can compare CT doses of their patient with national values to know whether their doses are comparable or not. Radiographers and Radiologist can participate effectively infirming both the public and other hospital personnel such as physicians about the dose in CT.

CT radiographers and radiologist can assist the medical physicist in performing the actual dose measurement. Radiographers and radiologist can be at the same time conducting the quality control procedures.

Finally, a knowledge of CT dosimetry will assist the radiographers and radiologist to carry our dose measurement themselves where there is no medical physicist to perform the task (Seeram, 2009).

2.3.8 CT Dose Measurement Parameters

Measurement of patient dose undergoing CT examination can be done directly on patient using Themoluminescent Dosimeter (TLDS) or on phantoms using either an ionization chamber or TLDS. It can as well be carried out indirectly through the measurement of CT Dose Index (CTDI), volume CT Dose Index ($CTDI_{Vol}$) Dose length product (DLP) or multiple Scan-Average Dose (MSAD) (Rothenberg & Pentlow, 1992; Ngaile & Msaki, 2006).

Dose measurement to determine CTDI and MSAD require the use of TLDS, and this is difficult and time-consuming for a wide survey of patient's doses.

Therefore, it is rarely performed (Marinet *et al.*, 2003). However, the use of $CTDI_{vol}$ and DLP been proposed as the appropriate dose quantities for the establishment of diagnostic reference levels for optimizing patients exposure (GE Medical System, 2001; American Academic of Physical Medicine and Rehabilitation, (AAPMR), 2008). The DLP plays an important role a an indicator of the radiation dose of the patient, because it takes into account the extent of the body region being irradiated (GE Medical System, 2001; AAPR, 2008). The DLP plays an important role as an indicator of the radiation dose of the patients, because it takes into account the extent of the body region being irradiated (GE Medical System, 2001; Livingstone *et al.*, 2006).

Equally, $CTDI_{vol}$ and DLP are dose parameters which can readily be recorded from the display units of most modern CT scanners since around 2001 (AAPMR, 2008).

I. **CT Dose Index (CTDI)**

CTDI is a measure of dose from a single slice of irradiation (Hung *et al.*, 2004). It is also, an important fundamental radiation dose parameters that increases dose awareness, and dose optimization in CT examination (Lewis & Edyrean, 2005). The CTDI is measured, and other radiation dose parameter like DLP and $CTDI_{vol}$ are derived from it. It is usually measured with thermoluminiscence dosimeters or an ion chamber. This measurement is labour-intensive, hence is rarely represented absorb dose, and the SI unit of measurement is Gray (ay). CTDI represent the integral under the radiation dose profile in the Z-axis of a single slice scanner that would produce 1 tomographic image per tube rotation (Morin *et al.;* 2003; IAEA, 2007).

II. **$CTDI_{100}$**

The $CTDI_{100}$ is a measured parameter of radiation exposure. It is obtained with an ionization chamber that integrates the radiation exposure of a single axial scan over a length of 100mm.

The ionization event occurring in the chamber produces a current that is proportional to the number of ionization events. The measured exposure can converted to dose. This measurement is more convenient that the CTDI, and is the measurement of choice performed by medical physicist in the clinical setting. The SI unit of exposure measurement is coulomb/kg(c/kg) (Morin *et al.;* 2003).

III. **$CTDI_W$**

The $CTDI_W$ is the weight average of the **$CTDI_{100}$** measured at the center and the peripheral locations of the phantom. This parameter reflects the average absorbed dose for a single cross sectional image of the patients body. The $CTDI_W$ is calculated using the equation:

$$CTDI_W = [2/3\ CTDI_{100}\ (Periphery) + 1/3\ CTDI_{100}\ (center)] \times F\ldots(Y) \quad (2.1)$$

“The term F reflects the difference between the absorption of radiation in air and the absorption in another media. It is used for convert radiation exposure, expressed in c/kg, into absorbed dose, expressed in Gy (the SI unit for $CTDI_W$). For calculation of CDI_W the appropriate value for F is 33.7Gy X C^{-1} K Kg^{-1} (Koller, *et al.,* 2003; Morin *et al.;* 2003).

IV. **Dose Length Product (DLP)**

DLP is an indicator of the integrated radiation dose of the entire CT examination. The DLP incorporate the number of slices and the scan width (total scan length). The DLP indicates most closely the radiation dose for a specific CT examination, and its numeric value is affected by variances in patient anatomy (the value of DLP is higher for taller patient because of their height).

So “the CDI_W is more useful in designing CT imaging protocols and comparing radiation doses among different protocols” (Morin *et al.,* 2003; Russels, *et al.,* 2008). The DLP is directly related to the patient (stochastic) risk, and may be used to set reference values for a given type of CT examination to help ensure patient does at CT are as low as reasonably achievable (Walter, Kent & Mohammad, 2008).

According to Edmond (2009), “DLP is found on the console of the CT scanners as required by low in many countries in Europe.

The DLP is expressed as $CTDI_{vol}$ X scan length. Therefore, DLP increases with an increase in total scan length or with variable that affect the $CTDI_W$ or $CTDI_{vol}$ such as tube voltage, tube current or pitch. Because scan length is expressed in centimetres, the SI unit of DLP is May X cm (Morin *et al.,* 2003).

V. **Multiple Scan Average Dose (MSAD)**

MSAD is the average radiation dose over the central scan of a CT procedure consisting of multiple parallel scan. The MSAD describes the average patient dose only if the scan protocol uses more than just a few parallel scans. Like the CTDI, the MSAD requires thermoluninescent dosimeters for measurement and is rarely performed (Morin *et al.,* 2003).

The MSAD for non-spiral scans can be estimated from the CTDI following Morin *et al., (*2003*)* as represented in the equation 2.2.

$$\text{MSAD} = \frac{NXT}{I}\,(CTDI) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.2)$$

Where N is the number of scans, T is the nominal scan with (mm), and I is the distance between scans (mm). For MSCT system, N X T is the total nominal scan width, and I corresponds to the patient table movement during 1 gantry rotation. Therefore, given the definition of pitch as the table movement per gantry rotation to be collimation (Karthikeyan & Chegu, 2005), the MSAD for spiral scans also can be expressed as; following the work of Morin *et al.,(* 2003).

$$\text{MSAD} = \frac{I}{Pitch}\,(CTDI) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.3)$$

VI. **$\mathbf{CTDI_{Vol}}$**

Volume computed Tomography Dose Index ($CTDI_{Vol}$) is expressed as the average dose delivered to the scan volume for a specific examination. It is delivered from the CTDI. $CTDI_{Vol}$ is also considered as a new radiation dose parameter agreed by the International Electrochemical Commission (Russels *et al.,* 2008).

According to Morin *et al.,* (2003) $CTDI_{Vol}$ for single-Slice scanners is defined as:

$$CTDI_{vol} = \frac{NXT}{I}\ (CTDI_W) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

When N is the number of scans, T is the nominal scan width (mm) and I is the distance between scans (AAPS). Also, $CTDI_{vol}$ for MSCT is defined as:

$$CTDI_{vol} = \frac{I}{Pitch}\ (CTDI_W) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

The $CTDI_{Vol}$ is now the preferred expression of radiation dose in CT dosimetry and is considered more useful in comparing radiation dose to critical organs such as the thyroid and lens for CT examination of neck (Morin *et al.*, (2003) Russels *et al.*, 2008).

VII. **Effective Dose**

Effective dose quantities the risk from partial body exposure to that form an equivalent whole body exposure. The term is used to take into account the type of radiation and the sensitivity to tissues to ionizing radiation (Seeram, 2009). In CT, effective dose is expressed following the work of Ling (2009) as:

$$E = E_{DLP}\ \text{X DLP} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

Where E= Effective dose

E_{DLP} = Normalised effective dose

DLP= Dose Length product

2.3.9 Radiation Dose in CT Examination

Even though CT delivers some of the highest dose during radiological examinations (Rothenberg & Pentlow, 1992), CT vendors do not believe that radiation exposure from CT scans present a significant health hazard (Mozundar, 2003). This is because, measured effective doses, from CT examination are well below the recommended limits of exposure (Mozundar, 2003). Despite that, CT examination are does limited imaging techniques, which can produce better images with increased radiation dose (Rethenberg & Penlow, 1992). Unlike conventional film screen radiography. To enhance optimization of patients exposure and image quality, the use of DRLS and adjustment of exposure parameters such as MAS & KV are necessary (Rethenberg & Penlow, 1992; Seeram, 2013).

2.3.10 Factors Affecting Radiation Dose in CT

In this section, factors affecting radiation dose in CT are discussed. These include the operating parameters such as the Kv, MAS & Slice thickness and indirect factors such as the reconstruction filter. The direct factors have a direct effect on the image quality, but not direct influence on the radiation dose (Seeram, 2009).

2.3.11 CT Scanner Design

Scanner design features affects radiation dose to patient. Most of the features of CT scanners that affect dose, and dose efficiency are similar in both single and multi-slice systems. Featuers of CT scanners that affect patient’s dose include: tube filtration, bema shaping filters, collimator design, and focus to axis distance. Those that affect dose efficiency include: detector materials, number, width and spacing. Indeed some manufactures have a range of systems from single slice to 16-slice which are identical in terms of most of the features. The only difference is that single bank of detectors of a single slice scanner is replace by multiple detector banks along the Z-axis. It is this factors which primarily cause difference in dose efficiency between single and multi-slice scanners (Lewis & Edyvean, 2005; Goldman, 2007). Also the difference in number of detector rows coverage but not the $CTDI_{vol}$ if parameters like KV and MAS are kept constant.

2.3.12 Contrast Media in CT Examination

The contrast used in CT examination can be either be positive or negative (Baert & Sarter, 2001). Positive contrast media can be iodinated or a diluted barium suspension, and may be administered orally, such as gas or water, may also be used in the examination. Both kinds of contrast may be used together to optimize the detection of abnormalities. CT examination can be carried out with or without contrast enhancement based on the clinical situation (Slone, 2000).

Pre-contrast series (without contrast enhancement) are carried out to demonstrate the presence of stone, or calcification or as a standard baseline before contrast enhancement. Contrast series are preferred in most cases to demonstrate different phases of blood intake in any organ or abnormal structures. Administration of contrast media is centra-indicated however, patient allergies to contrast media such as iodine. The turning of image acquisition after contrast administration is crucial to achieve the examination objectives. If arterial and venous phases are carried out, it is known as a biphasic series with current CT technology. Scanning after contrast media injection can be initiated automatically once the appropriated density. For example around 50 house field unit (HU) (Siemens 2000), is selected. A House field unit is a quantitative scale for describing radiopacity or image area or image density. For example, liver enhances about 40Hu within 30 seconds with 2.5 advantages in demonstrating abnormalities, it also increases the scan series, thus increasing scan volume which directly increases the patient radiation from dose.

2.3.13 CT Examination Protocols

Current CT scanners have present protocols installed in their system, as shown in table 2.1. The protocols allow the user automatically select appropriate parameters to be used for CT examination. Scan parameters include KV, MAS, Slice thickness and table speed and can also be manipulated manually after consideration of patient size, the organ involved and patient condition (Seeram, 2000).

Occasionally the user may choose specific organs to be examined which required different parameters to the original present parameters e.g. routine abdominal CT scan examinations include the upper abdomen and pelvis and is normally scanned with the patient requested to suspend end-expiration to reduce internal pressure and motion.

X-ray tube potentials normally range from 120 to 140kv while, MAS can typically vary from 210 to 330. These two scan parameters are vital for dose optimization with patient size. The selection of slice collimation may be from 5 to 8mm with a pitch of 1 to 1.6 for individual organs such as pancreas or kidneys, slice thickness may range from 2 to 5mm to allow detection of small lesions.

The applied protocols from different central affect the dose measured amongst scanners. To provide best practice the American College of Radiologists ACR (2001) and the European Commission European Commission (1998) have provided guidelines on CT protocols. The information includes appropriate protocols for parameters, image interpretation and quality assurance.

Table 2.1: Present Protocols Installed in Current CT Scanner

Regions	Organs
Upper abdomen	- Liver - Spleen - Pancreas - Adrenals - Kidney
Pelvis	- Prostate - Endometrial - Ovaries - Bladder
Upper abdomen & Pelvis	- Gastro intestine track - Peritoneum - Complex or several organs in different regions

(Adler & Canten, 2009).

2.3.14 X-rays

To better appreciate patient dose it is useful to review the process of the x-ray from production to patient interaction. Thus, this section will review the x-ray characteristics, its spectrum after filtration and the x-ray alternation concept.

2.3.15 X-ray Characteristics and Spectrum

X-rays are produce through two processes (Johne & Cunrigham, 1983) namely characteristic K-radiation emission and bristling production. The latter process produce more radiation than the former.

The intensity of radiation is proportional to the product of the number of photons and their energy.

The total spectrum can be simply represented by Equation (2.7) (Comber, 1996).

$I (E) = CZ (E_{Max} – E)$ ……………………………………………………………….(2.7)

Where

I(E) is the intensity at energy E

C is constant

Z is the atomic number of the target.

Thus, the resultant x-ray spectrum depends on the target material, energy applied and filtration the effect of filtration will be discussed below.

2.3.16 Filtration

X-ray beam filtration in CT may be provided by typical additional filters such as 4 to 6mm aluminum, 0.5mm copper and a beam shaper (Marshal, 1982; Nagel, 2000). The filtration in CT scanners may serve the two main purposes of

(1) Changing x-ray beam energy

(2) Changing intensity over the x-ray fan beam.

Filtration thus, hardens the beam by absorbing the "soft" (low energy) radiation so that a more homogenous beam work better penetration is utilized.

A specifically designed filter for CT known as bowtie or beam shapers used before the patient to compensate the attenuation across the patient thus provides uniform x-ray beam to reach the detector. These may reduce the intensity of the beam away from the centre of the scan filed. Both filtration techniques served to also reduce patient exposure.

2.3.17 Attenuation and Half Value Layer

The attenuation of x=-ray photons occurs when absorbed or scattered with in a medium. Liner attenuation is defined by Lambert Beer Law Equation (2.8) (Hendee & RItnour, 2002).

$I = I_0e\text{-}ux$ ………………………………………………………………………(2.8)

Where

I = the transmitted photon intensity

I_0 = incident photon intensity

x = the thickness of the material (cm)

μ = the liner attenuation coefficient (cm^{-1})

The factors that affect the liner attenuation coefficient are

(1) The energy of the beam

(2) Material characteristics including atomic number, density and the number of electrons per gram of the métier.

Increasing the energy will increase the number of transmitted photons and decrease the attenuation, while increasing the material density, atomic number and electrons per gram will increase the attenuation. Another fundamental attenuation coefficient is the mass coefficient which is obtained from the linear coefficient dividing by the density p. the mass attenuation coefficient (µm) or (µp) is independent of the density.

2.3.18 The Attenuation Coefficient

Is defined as the linear attenuation coefficient, µ and the dimensions of per cm. if the thickness is in g/cm^2 then the absorption coefficient is known as the mass attenuation coefficient. µm with its dimension is $(g/cm^2)^{-1}$ or cm^2/g. the relationship between µm and µ can be seen in the equation below, where p I the density of the absorber. Half value layer is the thickness of absorber required to reduce the intensity of a radiation beam by a factor of two. Thus;

$\mu m\ (cm^{-1}) = \mu m\ (cm^2, g^{-1})\ xp\ (g.cm^{-3})$

2.3.19 Distribution of CT Globally

The use of CT has increased rapidly, both in the USA and other parts of the world, notably in Japan, (Brenner & Hall, 2007). Survey conducted in 1966 has shown that, the number of CT scanners per 1 million populations was in the USA and 64 in Japan. It is estimated that more than 62 million CT scans are currently conducted each year in the United States, as compared with about 3 million in 1980 (Brenner & Hall, 2007).

The sharp increase in the distribution of CT scanners has been driven largely advance in CT technology that makes it extremely user-friendly for both the patient and the physician Garba (2014), coupled with improved radiation efficiency. Table (2.1) below, shows the distribution of CT scanners in the study sites.

Table 2.2: Distribution of Functional CT Scanners at the Study Site.

CT	Manufacturer	Number of defectors rows
Center A	General electric (GE) bright speed	16 slices
Center B	Philips Brilliance	16 slices
Center C	Toshiba Alexion	160 slices

(Graba, 2014).

2.3.20 Brain CT in Nigeria and its Role in Nigeria

Nigeria is one of the developing countries where the technology of CT is not widespread compared to developed nations like the UK and the United States of America (USA). This is because, with a population of 120 million only 30 CT machines are actively working based on the Nigeria Nuclear Regulatory Authority 2009 report. Garba (2014). Also, awareness of the clinical applications of CR is rather poor among general physicians and other healthcare providers (Erondu *et al.*, 2011). Despite the limited number of CT scanners, according to a study conducted by Idris Garba (2014), CT is referred to as the first line investigate modality of choice for patients with severe head injury. Although brain CT is the most common, to date, not literature has been documenting the rate of brain CT in Nigeria.

2.3.21 Chest CT in Nigeria and its Role in Imaging

Medical physicians have become more concerned recently about the somatic and genetic hazard associated with radiation exposure and absorbed dose to patients during chest radiographic examination (Alumuka *et al.,* 2014). Diagnostic radiology requires that measurement be made of the radiation dose received by patients during diagnostic procedure and this has come under scrutiny and monitoring in recent times (Alumuka *et al.,* 2014).

In both developed and developing countries, the number of X-rays facilities and X-rays equipment is increasing rapidly. Although alternative modalities (MRI) are becoming increasingly available (Alumuka *et al.,* 2014). Since improvements in the quality of X-ray images and patients protection have ensured that the use of diagnostic X-ray remains the most common and technique for diagnosis. This make it a major contributor to man’s exposure to artificial sources of ionizing radiation. Medical physicians have devoted much attention to the minimization of patients' dose in diagnostic radiology (Alumuka *et al.,* 2014). Substantial reduction in radiation dose to the patients resulting from radiographic procedures has been achieved in many countries.

Radiology personnel cannot quantitatively monitor does to the patients in every procedure, however, the magnitude of patients exposure resulting from the various radiological examination performed must be appreciated. The objective of radiological examination is to obtain information about internal anatomy of patients in order to provide adequate diagnostic date for clinician (Alumuka *et al.,* 2014). Chest radiography examination is the most frequently performed radiological procedure in Nigeria, which contributes to the most common use of X-rays leading to high population dose of medical irradiation. In chest radiography, tests are outside the exposed field, it would be very useful for clinical radiographers to know how and to what extent the testicular doses vary with tube potential in chest radiography, using both the high tube potential and the tube potential techniques. This knowledge will lead to appropriate exposure selection consistent with acceptable image quality (Alumuka *et al.,* 2014).

2.3.22 Abdomen CT in Nigeria and Its Role in Imaging

Abdomen CT in Nigeria and it role in Imaging abdomen CT is also very useful in the evaluation of a wide range abdominal conditions such as localization of abdominal masses, staging and re-staging of malignancies and follow-up of patients post-operatively after various abdominal surgeries (Yunusa *et al.,* 2016) undoubtedly, the need for conventional radiography has shown a gradual decline due to the increasing utility of helical CT in abdominal imaging (Yunusa *et al.,* 2016).

Computerized tomography (CT) is an X-ray diagnostic tools that offers easy and quick evaluation of abdomen, due to its high sensitivity speed of acquisition, and multi-planner capability (Yunusa *et al.,* 2016). Its speed and better tissue resolution when compared to untrasonography or conventional plain radiography allows it to be used in the early evaluation of acute abdominal conditions such as diagnosis of acute appendicitis and localization of oweteric caliculi (Yunusa *et al.,* 2016).

The abdominal injury is relatively common among both civilian ad military conditions and remains major source of morbidity and mortality especially when there is delay in diagnosis or treatment (Dogo *et al.,* 2000). In developed countries, advances in imaging modalities, patients monitoring devices and prompt intervention have improved the outcomes (Dogo *et al.,* 2000).

x-ray computed tomography (CT) has successfully enacted itself as a primary diagnostic modality (Abdulkadir *et al.,* 2016). Abdulkadir *et al.,* 2016 have also reported the increased utilization of computed tomography examination for clinical diagnosis worldwide. Fast scanning speed, isotropic spatial resolution, non-invasive, affordability compared to other modalities such as magnetic resonance imaging, application is staying, treatment planning, and follow-up of cancer treatment are some its unique advantages (Abdulkadir *et al.,* 2016).

Although CT imparts high radiation to patients, its benefits can for out weight to risk if all equipment, personnel and technical know how guiding the proper used of the equipment are well adopted (Abdulkadir *et al.,* 2016). New advancement in CT such as multi-slice which gives higher doses to the patient have also been reported to have led to further increase in the collective dose of CT examination (Abdulkadir *et al.,* 2016). As much as 1.5-2% of cancer may eventually be caused by the radiation currently used in CT (Abdulkadir *et al.*, 2016).

2.3.23 Operating Parameters for Head, Chest and Abdominal CT scan.

Various changes in selectable scan operating parameters affect patients radiation does. These includes changes in source collimation, section thickness, section spacing, and number of adjacent sections. Some scanners have a much wider choice of representing parameters than others (Piethenburg & Penlow, 1992). Previous studies have suggested that it is feasible to reduce tube current without marked deterioration if image quality in CT of the head (Korabulut & Ariyurek, 2006).

Other operating parameters that significantly affect radiation dose to patient are:

X-ray tube voltage: is the electrical potential applied across the x-ray tube to accelerate electrons toward the target material. Radiation dose increases approximately proportional to the percentage change in tube voltage (AAPM, 2013). Tube voltage values for routine brain CT scan for adult patients are shown in table (2.2).

Table 2.3: Typical TubeVoltage for Routine Brain CT Scan for Adult Patients

Kv	**References**
110	(Livingstone *et al.*, 2006)
120 – 140	(Smith *et al.*, 2007)
120	(Tsapaki *et al.*, 2006)

X-ray tube current; increasing the current (MA) increase the dose proportionality (Ling, 2009). Typical mass values for routine brain CT Scan for adult patient are shown in Table (2.3)

Table 2.4: Typical Tube Current for Routine Brain CT Scan for Adult Patients

MAS	References
110	(Livingstone *et al.*, 2006)
200 – 350	(Smith *et al.*, 2007)
250 – 270	(Tsapaki *et al.*, 2006)

Scan time: in a complete rotation of 360^0, dose is directly to scan time. If incomplete rotations are employed, there is a complex spatial relationship between dose and scan time because of variation in rotation angle. The exposure time may be significant less than the scan time for the scanner that employ a pulse x-ray beam.

Therefore a longer scan time leads to more radiation dose to patients (Rothenberg & Penflow, 1992). Thin slice section give more dose to patient because the CT scanner will take more time to cover the desired area of interest.

Scanner rotation angle: The desirable reconstruct angle for CT image is 180^0. Denta acquisition over 360^0 (or 360^0 plus beam) is widely used for third and fourth generation scanners. Over scan of 15^0 – 45^0 is often used to reduce patient motion and facts.

Some scanner may irradiate patients over a larger angle than that used for data collection as the tube accelerates and decelerates before and after the scan. Any rotation other than 360^0 in asymmetric dose distribution. This is most marked for 180^0 scans, which maybe employed when scanners operate in the fast-scanning modes such as that used for dynamic studies (Rothenberg & Pentlow, 1992). A rotation angle of 360^0 produces more radiation dose (Karthikeyan & Chegu, 2005). Equally, additional rotation generally contributes a greater percentage to the radiation dose more especially in a multi slice CT scanner (Lewis, 2005).

Filtration: is the scammer component that shapes the energy of the x-ray spectrum. Beam shaping is done using other a bow the filter and/or hat filters. The radiation output from the x-ray tube ($CTDI_W$) is affected by a change in beam shaping filters. The relationship is render and filters specific (AAPM, 2013).

Patient Orientation: (Supine or prone position) may significantly affect the dose to critical organs such as the eyes when acquiring the scanogram (ling, 2009) and gonad in abdominal CT where acquiring scanogram. The chance of the effect becomes higher when the x-ray table is at the fronto-occipital position (in brain CT). This is because the critical organ (the eye) is closer to the since of radiation, like wise the gonad in abdominal CT. unfortunately this less important in brain CT scan, because in modern CT scanners the orientation of the x-ray tube could be changed from fronto-occipital to occipito-frontal positron. In addition, the gem try could be angled to minimize dose to the lens of the eyes without changing the patient position.

Source of collimation: x-ray Bearn collimation defined the beam width for examination wider Bearn collimation however, more penumbra which does not contribute in image formation but rather affect the radiation dose (Seeram, 2009).

Section thickness: in creasy the section thickness yields a slightly lower dose per sean as well as decreased noise.

Decreasing the section thickness while keeping noise constant results in higher radiaton dose (Rothernberg & Pentlow, 1992; Lewrs & Edyrean, 2005). Common slice thickness employed for routine brain CT scan are showing in Table (2.4)

Table 2.5: Common Section Thickness for routine brain CT scan

CT Scanners	Slice Thickness	References
GE 98000	10mm	(Smith *et al.*, 1998).
Toshiba Asteuon	2mm	(Koller, Eatough & Beltridge, 2003).
Siemans AR	10mm	(Tsakpaki, Kottou & Papadimitriou, 2001).
Philips brilliance	3mm	(Zarb *et al.*, 2013).
GE Briht speed	2.5 – 5mm	(Zarb *et al.*, 2013).

Table 2.6 Common Section thickness for routine chest CT

CT Scanners	Slice Thickness	References
GE brightspeed	0.625 – 1.25mm	Ver 7^{th} May, 2007.

Pitch: defined on based on the international electrotechnical commission standards, as the table travel divided by the total active detector length in the Z-axis (GE Medical system 2001).

Most manufacturers give pitch volume with respect to the nominal slice thickness instead of the total active collimated length in the Z-direction. This definition of pitch is easier to use in both single and multi-slice systems. In helical CT, selecting a higher pitch will reduce the DLP of the patient but not the CIDI, by the reducing the number of rotations over the same place (GE Medical system, 2001; Seeram, 2009) number of adjacent sections: increasing the number of adjacent increases the volume of tissue irradiated and increases the dose to any individual region of the patient when the dose profiles overlap (Seeram, 2009).

Repeat scan: repeat scans of the same region increase radiation dose to patient (Seeram, 2009).

Image parameters: selectable image parameters such as pixel size and reconstruction filter do not affect dose directly. The dose however, varies when a change in these parameters requires a different milliamperage or scan time to obtain the desired image quality (Rothv & Pentlow, 1992; Ling, 2009).

Standard scan examination: outline of scanning procedure for a particular clinical indication that is generally accepted as being able to provide adequate clinical information in most of the patient examination. Radiation dose are usually lower than that of special techniques (Karthikeyan & Chegu, 2005). In a study conduct by Seifert, Hergen, Bartylla and Bla (1997) they stated that dose reduction from 0.9msv to 0.7msv without significant change to image quality is possible if the scan is done with standard exposure factors such as 120kv, 25mas, 5mm nominal slice thickness and with distal slice increment less than one instead of scanning with 120kv, 250mas, 0.5mm or 1mm slice thickness with slice increment greater than one.

The patient: dose distribution depends on the size, shape, tissue, density and elemental composition of the patient across section. The same scanner types with some operating technique would have different dose distributions for different body parts. A thicker patient section or dense tissue results in more buildup of scattered radiation. The dose at any point in the section is the sum of contributors from many beams, which may have undergone different amounts of attenuation (Rothenberg & Pentlow, 1996) recommended that measurements be performed on standard sized patients or patients dose to standard size, preferably with an average weight, that is 70+ 3kg.

2.3.24 DRLs at Local Level

The new medical exposure regulations in ht UK requires that, all hospitals to have procedures in place for establishing DRLs, for the regular assessment of patient doses and checking compliance with DRLs. (wall, 2000). Periodic measurement for the purpose of assessing presenting patient doses are also required by other legislation dealing with quality assurance of medical imaging equipment.

There are basically three options available to hospitals for establishing DRLs and locally.

i. They can either adapt the national DRLs,

ii. Use regional patient dose data to derive essentially regional DRLs and

iii. Adopt them for local use, or their own hospital close data to derive reference levels that are specific to their own practices

In order to ensure representative results, a successful survey requires the timely collection of essentially scan data term from a robust sample in relation to a core of key examination covering common CT practice (Shrimpton & Hillier, 2014)

2.6.2 Method of Collecting Local Dose Indicator

In order to obtain meaningful values, measurement most be carried out in a significant numbers of patients (20 is a minimum) or experiments with pantherms. Thus for each given procedure the average of these measurement can be considered as local dose indicator of the department. They are measured in priority for the most common procedures and for those which deliver the highest doses (Bourgingnon, 2009).

2.6.3 Method of Establishing DRLs

The guidline for establishing DRLs as mentioned by the Eruopean commission are as follows:

❖ DRLs for diagnostic radiology should be based on doses measured in various types of hospitals, clinics and practices and not only in welt-equipped hospitals.

❖ As mentioned before, because of patients and the information required differ widely, DRLs are only applicable to standard procedures, standard phantoms or groups of standard – sixed patients, and for specific groups of children distinguish by age, size and weight

- ❖ DRLs can be assessed using entrance surface doses, measured with a TLD fixed on the patients body
- ❖ For CT, the weight CT Dose index (CTDLw) and the Dose length product (DLP) are suitable quantities to be used as DRLs
- ❖ DRLs are particularly useful for more common examinations which may involve high doses or are frequently performed.
- ❖ When setting DRLs for procedure performed with digital systems, it is important to remember that the level of image quality can be selected by the user, or automatically set by the X-ray system.
- ❖ A minimum of ten (10) patients could be considered per examination.

2.6.4 Critical for Radiation Dose to the Patient

Consideration of dose constraint has particular importance in CT, since this is recognized as a relatively high dose modality. ICRP has recommended the dose constraint concept for medical exposure, which is translated to diagnostic reference levels for diagnostic radiography. The application of this concepts in line with reference dose values for a standard sized patients indicated in the previous European Guideline.

In the present guidelines, tentative reference dose values for CT have been established for selected examination in order to facilitate comparison of examination protocols used in difference deportment, and with difference types of equipment.

Diagnostic reference dose values provide quantitative guidelines to help identify relatively poor or inadequate use of the techniques rather than an indication of satisfaction performance.

2.7 Prevalence of CT DRLs in the World

The idea of diagnostic reference levels in CT have been established in many countries in the world. The prevalence of established DRLs is shown in the Tables (2.1-2.2).

Table 2.7: Prevalence of Adults DRLs based on CTDI (MGy) values.

Country	EC	Ireland	Malta	Kenya	Portugal	3rd UK	Syria	Austria
Authors	(European union, 2014	(Iflya et al.2012)	(zarb, Mc enfee et al.2012)	(Wambari, et at.2010)	(Samtos, et al.2014)	(Shrimpton PC et al.2014)	(Kharitas Khazzan, 2010)	ARPNSAF
Head CT	60	66-58	41	51	75	63	60.7	47
Chest CT	10	10-9	13.1	21	14	65		
Abdominal	35	12.3	12.1	21	18	20		

(Bourgingnon, 2009).

Table 2.7 Prevalence of Adults DRLs based on DLP (May Cm) Values.

Country	EC	Ireland	Malta	Kenya	3rd UK Survey	Syria	Portugal	Australia	Germany
Authors	(European union, 2014	(Folaley et al, 2012)	(Zarb Mcenters et al., 2012)	(Wambaniet al, 2010)	(Strumpton, PC et al. 2014)	(Kharsta & Khazzam, 2014)	(Santos, et al.2014)	ARPNSA	European society of Radiology, 2011)
Head CT	1000	940	736	1,364	970	793	1010	524	950
Chest CT	600	393	492	745	610	520	470	447	400
Abdominal	800	598	534.4	1143	745	252	800	696	900

(Bourgingnon, 2009).

2.8 Review of Related Works

In 2011, MC Entet *et al., (2012)* evaluates CT radiation dose in malt interms of $CTDI_{vol}$ and DLP was made the following European Commission Guidelines" the Maltese third quartile reported values and hence DRLS for $CTDI_{vol}$ (Abdomen:539.4 May CM^{-1}; Chest:492 May CM^{-1}; Chest:492 May CM^{-1}; headL736 May CM^{-1};) of the participating CT units do not demonstrate a significant difference to the recommended international CT scan in malta appears to be consisted with current standards of good practice .

In Syria, Kharita and Khazzam (2010) or examine or investigated the radiation dose of city and it was compared with similar studies in difference countries. This work surveyed 30CT scanners from 6 different manufactures distributed all over Syria. Typical doses from CT scanners in Syria are summarized in table 1.1-1.4), as third quartile values over the whole survey, for CTDI (Abdomen:24.1 May CM^{-1}; Chest:520 May CM^{-1}; head: 793May CM^{-1}). It was found that most CTDI and DLP values in this work were similar to the European reference levels and in line with the results of similar surveys and in the world. The results were in good agreement with those reported in various national surveys and with the UNSCEAR Report.

The result of CT dose survey obtained from Portugal in 2013 by Senatos *et al., (2014)* with the view of establishing national and dose data that collected retrospectively. The proposed national CT DRLS ($CTDI_{vol}$) for adult were 75,14 May for head, chest and abdomen, respectively and DLP were 101,470,800 May CM^{-1} for head, chest and abdomen, respectively from the finding, it shows that Portuguese DRLs were generally higher than European recommendations, suggesting potential for optimization. The threshold for greater standardization of CT protocols was identified.

The European Commission (2014) has recommended the most common DRLs values for CT examination, were DRLS in terms of $CTDI_{vol}$ (Abdomen:35May; Chest:10 May; head: 60May) and DLP (Abdomen:800 May CM^{-1}; Chest:600 May CM^{-1}; head: 1000May CM^{-1}). Therefore, each new established DRLs are expected to be consisted with the European Commission guidelines.

Abdomen CT was investigate by Yunusa *et al., (*2016*)* in Nigeria and it role in Imaging abdomen CT is also very useful in the evaluation of a wide range abdominal conditions such as localization of abdominal masses, staging and re-staging of malignancies and follow-up of patients post-operatively after various abdominal surgeries undoubtedly, the need for conventional radiography has shown a gradual decline due to the increasing utility of helical CT in abdominal imaging.

Computerized tomography (CT) is an X-ray diagnostic tools that offers easy and quick evaluation of abdomen, due to its high sensitivity speed of acquisition, and multi-planner capability (Yunusa *et al.,* 2016). Its speed and better tissue resolution when compared to untrasonography or conventional plain radiography allows it to be used in the early evaluation of acute abdominal conditions such as diagnosis of acute appendicitis and localization of oweteric caliculi (Yunusa *et al.,* 2016).

The abdominal injury is relatively common among both civilian ad military conditions and remains major source of morbidity and mortality especially when there is delay in diagnosis or treatment (Dogo *et al.,* 2000). In developed countries, advances in imaging modalities, patients monitoring devices and prompt intervention have improved the outcomes (Dogo *et al.,* 2000).

x-ray computed tomography (CT) has successfully enacted itself as a primary diagnostic modality (Abdulkadir *et al.*, 2016). Abdulkadir *et al.*, (2016) have also reported the increased utilization of computed tomography examination for clinical diagnosis worldwide. Fast scanning speed, isotropic spatial resolution, non-invasive, affordability compared to other modalities such as magnetic resonance imaging, application is staying, treatment planning, and follow-up of cancer treatment are some its unique advantages (Abdulkadir *et al.*, 2016).

Although CT imparts high radiation to patients, its benefits can for out weight to risk if all equipment, personnel and technical know how guiding the proper used of the equipment are well adopted (Abdulkadir *et al.*, 2016). New advancement in CT such as multi-slice which gives higher doses to the patient have also been reported to have led to further increase in the collective dose of CT examination (Abdulkadir *et al.*, 2016). As much as 1.5-2% of cancer may eventually be caused by the radiation currently used in CT

Table 2.8: Distribution of Functional CT Scanners at the Study Site.

CT Center	Manufacturer	Brand/ Model	Number of defectors rows	Year of Manufacture	Year of Installation
Center A	Philips	Brilliance	16 slices	2008	2009
Center B	Simen	Alexion	32 slices	2015	2015
Center C	General Electric (GE)	Bright Speed	16slices	2008	2014

(**Abdulkadir *et al.*, 2016)**

CHAPTER THREE
MATERIALS AND METHODS

3.1 Materials

The materials required for the conduct of this research include;

i. Computer tomography scanner machines located at the study centers.

   The plate 3.2, 3.3 shown the types of CT scanner machines used during the study period.

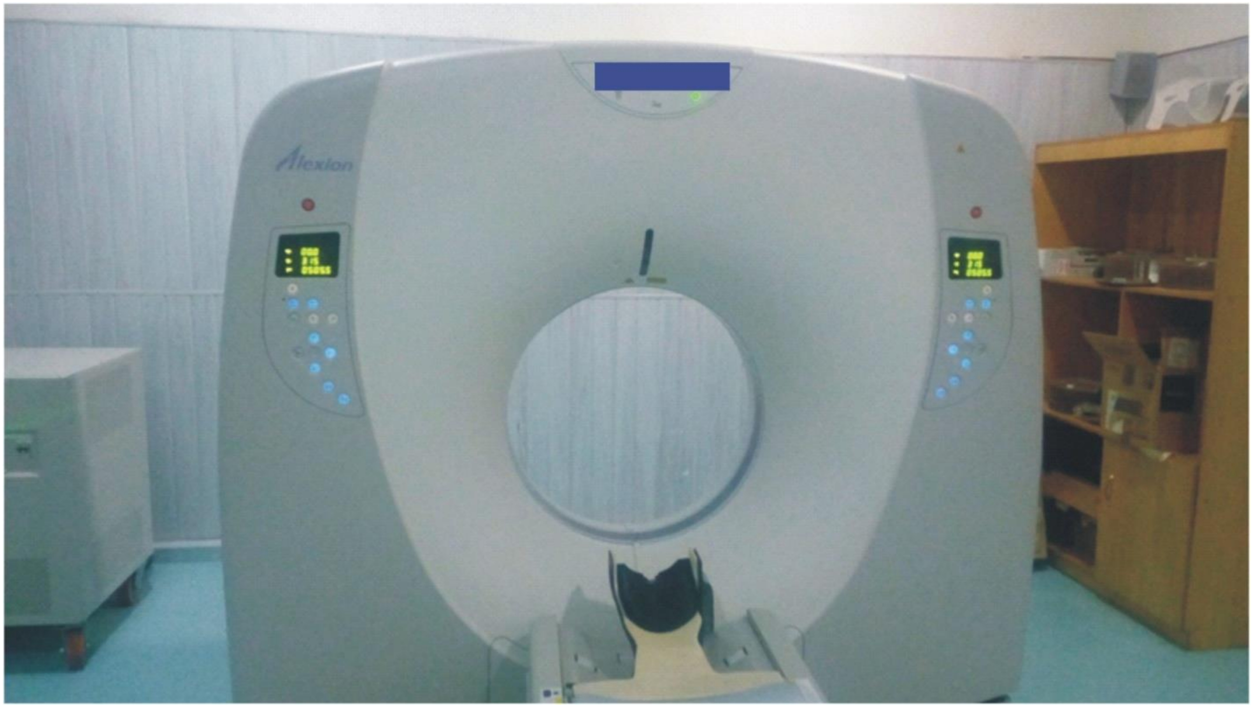

Plate 3.1: Philips Brilliance 16-slice from one of the study center
(Radiology department, National Hospital Abuja Nigeria, 2018)

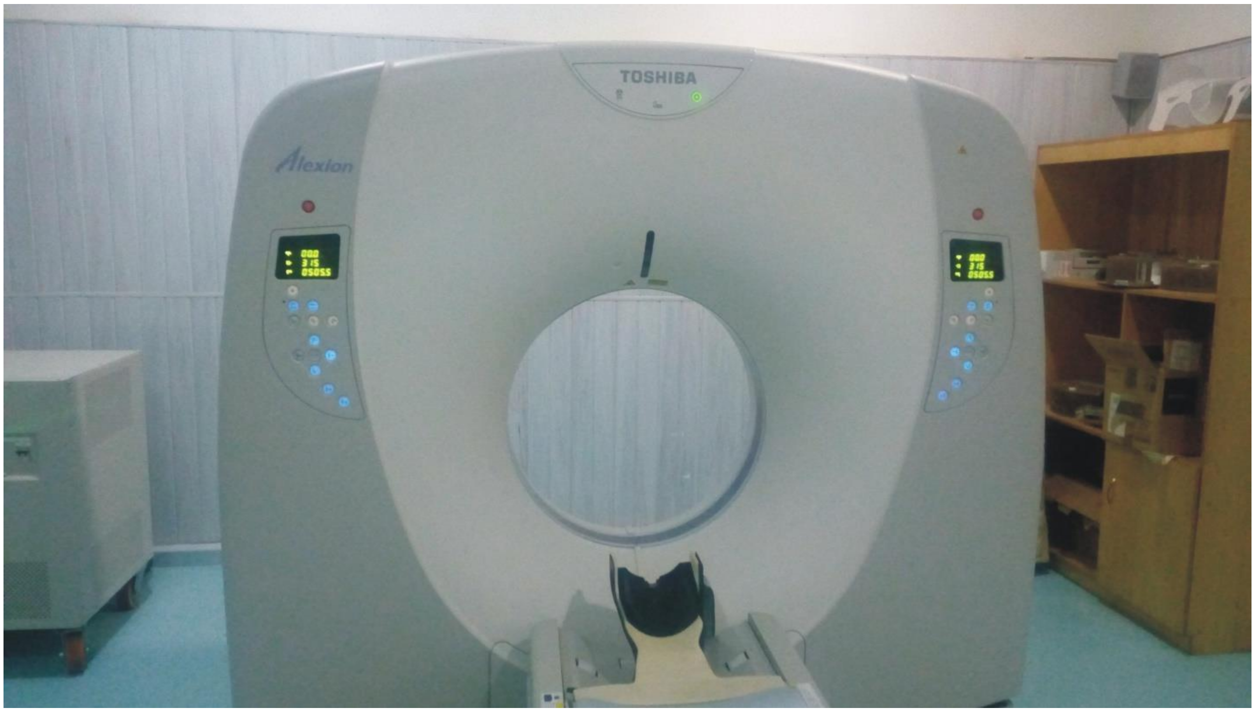

Plate 3.2: Toshiba Alexion 32-slice from one of the study site

(Radiology, Garki Hospital, FCT Abuja, Nigeria, 2018)

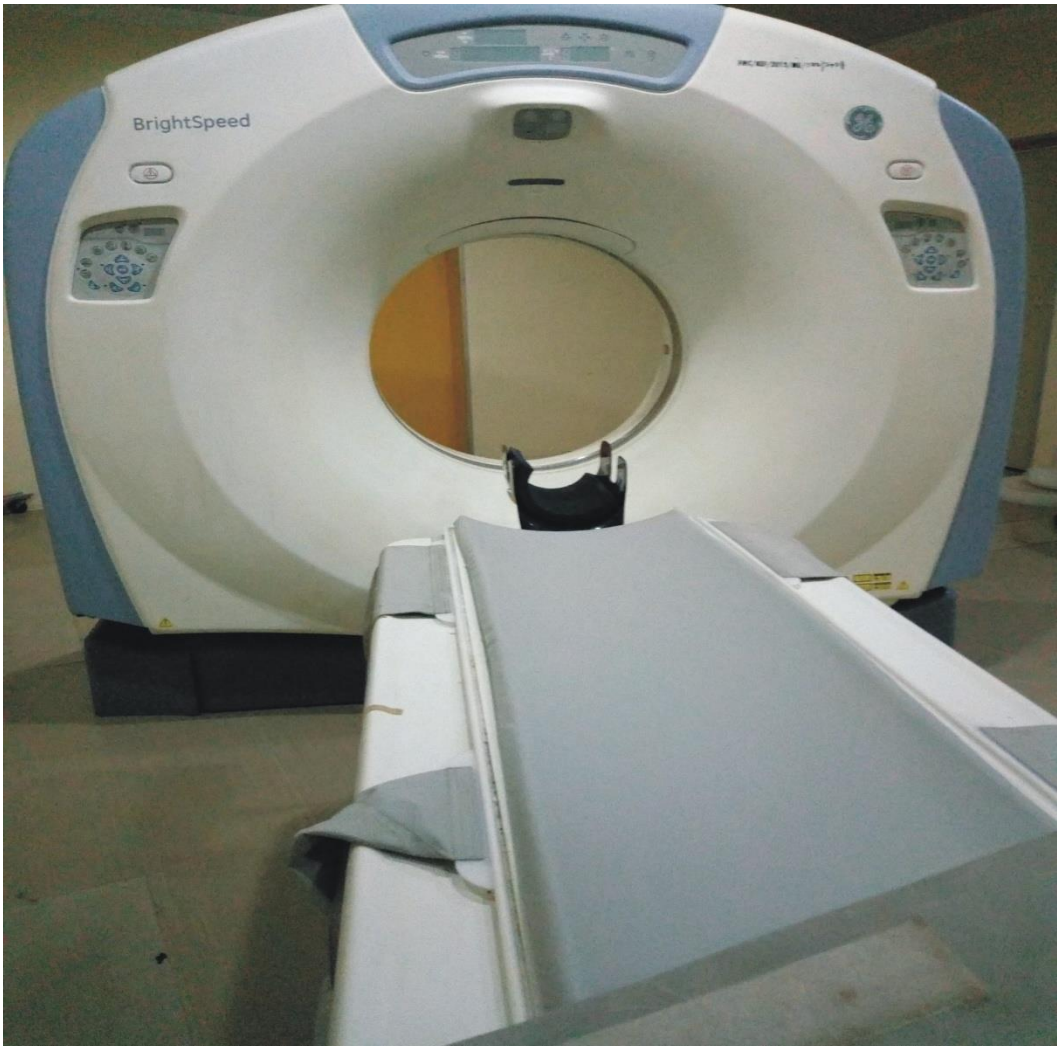

Plate 3.3: General electric (GE) Bright speed from one of the study site

(Radiology department, federal medical center Keffi, Nasarawa State, Nigeria, 2018)

Plate 3.4: Display CT scanner monitors Philips 16-slice which contained patient information, exposure parameters and radiation dose report from one of the study site.

ii. Data Collection Sheet

iii. SPSS version (20) software for data analysis

iv. Ethical clearance from the participated hospital that allowed this research to be conducted (appendix B.D)

3.2 Methods

The study adopted a retrospective and quantitative design to determine the absorbed radiation dose to patient undergoing CT scan of the head, chest and abdomen. A quantitative design was appropriate because the study involved the uses of numerical data, was conducted retrospectively to ensure more reliable and valid data (Punch, 2006), and acquired from the computer archive system, where the dose report and exposure parameters are stored.

3.2.1 Study Population

The study consisted of all adult patients that attended for CT scans examinations of head, chest and abdomen.

3.2.2 Methods of Data Collection

The data was collected by me with the assistant of the CT radiographers who are well trained on how to collect the data. The data collection sheet used for the study was adopted from the IAEA, survey from (Appendix A) and has the following sections: participant demographic information, scan parameters and dose parameters.

3.2.3 Toshiba Protocol for Routine Adult CT at the Study Site

For Toshiba CT scanner, a sequential (Axial) mode is maintained for routine head CT scans and (helical) for the chest and abdomen. The kilovotage used is 120k for head and chest and 100kv-120kv abdomen CT. in the Toshiba machine, the tube current time product (mAs) is recorded instead of tube current (mA) as in the case of the GE machine. The average mAs prescribed is 22mAs for head for the chest and abdomen ranged from 38mAs-220mAs. A pitch of 51is used for head CT and 111mm, 65mm for chest6 and abdomen CT respectively. Single values for DLP and CTDI recorded.

3.2.4 Philips protocol for routine adult CT scan at the study site

For Phillips CT scanners, the protocol is slightly different. A sequential (Axial) mode is also maintained for routine adult lend CT scans. The slice group is single as opposed to the GE protocol which has two groups. The kilovoltage used is 130kv. In the Philips machine, the tube current time product (MAS) is recorded instead of tube current (MA) as in the case of GE machine. The average MAS prescribed is 450. A uniform slice thickness of 3mm is used for the entire scan length. Single values for DLP and CTDIW were recorded since only one slice group is used.

3.2.5 General Electrical (GE) CT Scan Protocol for Routine Adult at the study Area

The protocol for routine adult CT scan is designed to be in sequential (Axial) model while the chest and abdomen is (helical) model for GE 16-slice. The mA used is in the range of 140mA-199mA with kilovoltage 100kv for head CT, 62mA-128mA, 70mA-160mA for chest and abdomen with 120KV each for the GE 16-slice. The protocol for GE 8-slice is (helical) mode and the mA range of 100mA with 100KV for both head, and abdomen CT.

The time used for GE 16-slice is 2 second for head CT, 1 second for chest and abdomen Ct per slice, and also 1 second per slice for 8-slice GE scanner.

In most cases, automatic mA is prescribed due to its does saving effect. The pitch in GE 16-slice scanners is 0.93mm and 0.75mm for GE 8-slice values for DLP and CTDI were recorded.

3.2.6 Participant Demographic Information: The Demographic Information Included in the Study Was:

i. Age, to make sure only adult patient were included in the study.

ii. Gender of the patient.

iii. Weight to ensure that only standard size patients were included (70Kg±3)

iv. Body region which indicates only patient coming for head, Chest and Abdomen CT were included in the study.

3.2.7 Scan Parameters

The exposure parameters were; tube current time product (MAS) and KV. Other information recorded was: slice thickness, pitch, scan length number of slices, scan mode, rotation time, scanning range and field of view (FOV).

3.2.8 Dose Parameters

After each head, chest and abdomen CT scan, the CTDI and DLP values obtained from the visual display unit of the CT scanners were recorded on a data capture sheet. These are the parameters found in all of the CT scanners in the study. The scans were done using the existing protocols. This gave a reasonable reflection of what was happening at the study site. Weighty scales were provided by the researcher in all the participating centers.

The most senior Radiographers' incharge of the CT units were responsible for explaining the procedure and weighing of all the participants. Hence; the radiographers were properly trained to be able to administer the consent information to all the participants.

They were also able to determine whether he patient could be included in the study or not.

3.3 Sample Size

A simple size (60) participant patient was recruited for head CT head in the study. This was obtained through selection of 20 participants each that come for CT examination o the head in center A, B and C respectively.

In chest CT examination, a simple size of (26) participant was used in the study. This was obtained through selection of 16 participants from center A and 10 participants from center C while center B has zero participants. In the abdominal CT examination, a total of (45) participant was used in the study. This was obtained through selection of 15 participants from center A, 20 participants from center B and 10 participants from center C respectively using a purposive method of sampling (Tongco, 2007; Garba, 2014). The variation in the number of sample size occurred because of the limitation of the participated patients in the study centers. Therefore, purposive sampling technique was considered as the most appropriate as standard-sized patients are essential to the design (Garba, 2014).

Based on the recommendation guideline for sample recruitment made by the European commission which says a minimum of 10 participants shall be recruited for each body part under examination (European commission, 1999). Furthermore, the larger a sample, the more representative it will be of the population from which it has been taken (Willis, 2014; Garba, 2014). All patients that met the inclusion criteria and agreed to participate in the study were weighed, and were within the weight limits of standard size patient which is 70±3kg for the European population (European commission, 1996). The

European weight limit was adopted to make comparison with published values easier because a standard-size patient for Nigeria population could not be found in the literature.

3.3.1 Inclusion Criteria

i. Only adult patients weighing in the range of 67 to 73kg were included in the study (European commission, 1999; Garba, 2014).

ii. Only adult patients that attended for routine CT scans of brain, chest and abdominal CT scan examination was considered.

iii. Data was acquired on a CT scanner that was calibrated by the Nigeria Nuclear Regulatory Authority (NNRA).

3.3.2 Exclusion Criteria

i. Patient that attended for non-routine CT procedure such as CT angiography, CT colonography.

ii. Patients with weight above or below the specified limit (Garba, 2014).

iii. CT scanner that was not calibrated by the Nigeria Nuclear Regulatory Authority (NNRA).

3.4 Data Analysis

The data obtained were saved on an excel spread sheet (appendix J, K & L). The data contained the followings: the demographic information (age, gender and weight). The scan parameters (KV, MA, MAS, Rotation time, Pitch and scanning range) and dose parameters (CTDI & DLP). The data were analysed to provide answers to the research problems itemized in chapter one, two statistical methods were employed for the data namely: descriptive and inferential analysis.

The descriptive analysis was employed to summarise the data for this study they are used to give a descriptive of the data by the determining the measures of location (mean, median and mode) and to express its variability (range, standard deviation and standard error) (Willis, 2004; Garba, 2014).

Inferential statistical analysis was employed to measure the significance (whether any difference between two samples is due to chance or a real effect of a test result). It is represented using P values (Willis, 2004; Garba, 2014).

Data was analysis using statistical packet social sciences (SPSS) version 22 software. The mean standard deviation and third quartile value at 95% confidence interval was used (Garba, 2014). Comparison was made between the measured doses and reported data from the European countries where there are established DRLs. Statistically significant results of dose values between CT centers were determined using chi-square and student t-test at 0.05level of significance (Willis, 2004; Garba, 2014).

3.4.1 T-test

The T-test is a statistical test used to compare paired but independent samples. It is used when the sample size is less than 30 (Garba 2014). In this study the sample taken from each of the center is less than 30.

3.4.2 Level of Significance

In a statistical analysis one must test the certainty of accepting the null hypothesis. Before this is done the level of significance for the rejection of the null hypothesis must be determined (Garba, 2014). Although the level of significance could be set at any value, it is usually set at 5% $P < 0.05$. This means the livelihood the event occurs by chance alone is 5 or lesion 100. (Therefore, there is 95% probability that the null hypothesis is correct).

The lower the level of significance that is adopted the less likely that the null hypothesis will be rejected (Garba, 2014).

3.4.3 The Mean

The mean summarizes all of the data. It is calculated by adding all the values and dividing the sum by the number of observations (Garba, 2014).

3.4.4 Third Quartile

The DRL must be set at approximately the level of the third quartile in the dose distribution. The third quartile value is chosen as an appropriate investigation level on the grounds that if 75% of x-ray departments can operate satisfactorily below this dose level, the remaining 25% should be made aware of their potentially less than optimal performance. They should then be encouraged to alter their radiographic equipment or techniques to bring their doses in line with majority (European commission, 1999).

3.4.5 Data Capture Sheet

The data collection sheet used was adopted from the IAEA document (2007), and it had been tested in other countries like Canada, Greece and India where similar studies had been conducted (IAEA, 2007; TEDDC, 2009). The recorded data were thoroughly checked (i.e data were entered into an excel spread sheet). Each entry was then checked by the researched to ensure that no mistakes were made during data capture) by the researcher before entered in the software for processing (Garba, 2014).

3.4.6 Ethical Consideration

Ethical clearance is the process that requires researchers to give due consideration to a participant in a research study (Garba, 2014). Researchers are asked to consider and document ethical clearance for any study involving human research participants. A researcher ethical responsibilities include the principle of academic integrity and honesty, and respect for other people (Garba, 2014). There are ethical issues in research which relate to patient access, consent and protection. For this reason, researchers are required to obtain permission to conduct their research (Punch, 2006). Refer to the permission from the study was obtained the chairperson responsible for the research in the participating hospitals (appendix B-D) as well as the research approval from the Department of Physics, Faculty of Natural and Applied Sciences Nasarawa state University Keffi-Nigeria (NSUK).

3.5 Study Area

Federal capital Territory (FCT) Abuja,

Abuja is planned city, research have it that it was built in 1980s, its shares boundary with Kogi, Kaduna, Niger and Nasarawa, it is in the central region of the country which is one of the reason it was chosen as the federal capital territory.

According to the United Nation (UN) Abuja is one of the fastest growing city in the word and the fastest growing city in African continent, it grew by 139.7% between the year 2000-2010. Abuja occupies a land area of 7,753.9sqkm while other sources are of the view it occupies, 8,000sqkm. It is a highly populated state with over three million people in its unofficial metropolitan area, making it the fourth largest metropolitan area in Nigeria, suspassed by Lagos, Kano and Ibadan. In the year 2016 the metropolitan area of Abuja is estimated at 6 million persons.

Abuja vegetation is mainly savannah with limited forest areas. The produce crops like Yam, beans, maize, millet and sorghum. Its minerals resources includes day, morable, iron, ore feltpare, gold and tank.

The indigenous inhabitants of the state comprises the Gwari, Koro, Gwandara, Ganagana, Afo and Bassa ethnic groups, primary dairy farmers, Hausa and Fulani also lived in the territory.

Fig. 3.5 Map of Federal capital Territory (FCT) Abuja, Showing the Study Area (Field Survey, 2017)

Keffi town, Nasarawa State, central Nigeria. It was founded about 1800 by Abdu Zanga (Abdullahi) a Fulani warrior from the north who made it the seat of vassal emirate subject to the emir of Zaria (a town 153miles (246km) north). Although, Keffi paid tribute to Zaria through the 19th century. It was constantly raided for salves; its war in the reign of Sidi Umaru (1877-94) with the nearby town of Nasarawa resulted in a further payment of slaves to Zaria.

Must of the inhabitants of the traditional emirates are Gwandara people engaged in tin and columbite and mining and farming, the chief crops are millet, sorghum, yams and cotton.

Keffi town has university, school of health technology, teachers college etc.

Keffi town is located just west of junction of Local roads that given it access to Abuja, Nasarawa, the trunk high to Akwanga and the main railway at Lafia.

Keffi town has a population of 92,664 according to census.

(www.britanica.com/place/keffi).

Fig. 3.6 Map of Keffi Showing the Study Area
(Field Survey, 2017)

CHAPTER FOUR
RESULTS

4.1 Result of the Number of Participants

In this study, the number of participants included for head CT are 20 each from centre A,B & C. This contained 37 (617%) male and 23(38.3%) females.

For chest CT, only center A & C received a total of 16 and 10 respectively within the study period, while center B has no participant. This consisted of 16(61.5%) males and 10 (38.0%) female.

In the case of Abdomen CT, 15,20 and 10 participants was obtained from center A, B and respectively. This gives a total of 23(51.1%) males and 22(48.9%) females. The participants' age range was from 16 to 80 years. Therefore, sixteen years of age is considered as an adult based on the hospital age classification in Nigeria (Garba, 2014).

Table 4.1. and 4.3 show the detailed information on the number, gender of the participated patients.

Table 4.1: Detailed Information on the Participants from Centre A.

CENTRE A	NUMBER OF MALE	NUMBER OF FEMALE	TOTAL
Head CT	12	8	20
Chest CT	5	10	15
Abdomen CT	6	10	16

Table 4.1 represents the detailed information of the participants from Centre A, where the total number of participants, the number of male and female for the Head, Chest and Abdomen CT are indicated.

Table 4.2: Detailed Information on the Participants from Centre B.

CENTRE A	NUMBER OF MALE	NUMBER OF FEMALE	TOTAL
Head CT	13	7	20
Chest CT	NA	NA	NA
Abdomen CT	6	14	20

NA = Not Available

Table 4.2 represents the detailed information of the participants from Centre B, where the total number of participants, the number of male and female for the Head, Chest and Abdomen CT are indicated.

Table 4.3: Detailed Information on the Participants from Centre C.

CENTRE A	NUMBER OF MALE	NUMBER OF FEMALE	TOTAL
Head CT	13	7	20
Chest CT	5	5	10
Abdomen CT	6	9	15

Table 4.3 represents the detailed information of the participants from Centre C, where the total number of participants and the number of male and female for the Head, Chest and Abdomen CT are indicated.

4.2 Result of Selected Patients Characteristics from the Three Study Centers.

Analysis of patient's characteristics (age, Weight and number of patients per each CT examination) is presented in Table 4.4. The recorded data in this study for patients characteristics (age and weight was reported to the nearest whole number).

Table 4.4: Result of Patient Characteristics

CT CENTRE/EXAMINATION		Age (years) Mean ± 50)	Weight (Kg) (Mean±SD)
Centre A			
Head	20	57.5±10.7	64.4±15.9
Chest	15	54.0±11.5	75.4±19.5
Abdomen	16	49.3±12.7	71.6±20.9
Centre B			
Head	20	55.3±11.5	77.2±25.0
Chest	NA	NA	NA
Abdomen	20	50.3±11.3	81.7±27.6
Centre C			
Head	20	60.3±14.3	62.4±16.1
Chest	10	60.8±11.7	63.3±5.4
Abdomen	15	50.3±9.6	52.6±11.6

4.3 Results of Measurement CT Scan exposure Parameters

Analysis of the scan parameters (kV, mA, mAs, Scan time and Scan range) for the three study centers is presented in Table 4.5.

Table 4.5: Result of Measure CT Exposure Parameters for Organ Dose Measurements

CT Examination	kV	mA	mAs	Scan time (S)	Scan Range
CENTRE A					
Head	120	NR	324.2±75.7	29.7	198.2±42.5
Chest	120	NR	153.3±12.5	13.4	362.7±38.6
Abdomen	120	NR	212.5±9.7	15.2	418.3±18.8
CENTRE B					
Head	120	NR	152.5±10.9	0.75	174.1±16.1
Chest	NA	NA	NA	NA	NA
Abdomen	100	NR	76.9±43.0	0.75	433.0±63.0
CENTRE C					
Head	120	237.7±29.6	NR	1.0	121.3±14.9
Chest	100	108.2±38.1	NR	0.75	342±35.6
Abdomen	120	268.9±113.5	NR	0.65	385.9±35.5

NA = Not Available
NR = Not Recorded.

The main kV values for head CT in Centre A, B & C are the same. The Chest CT has different kV values in both the centers (A, B & C) but there is no available data for chest CT in Centre B during the study period, in the abdomen, Center A & C have the same value while that of centre B is different.

The mean mAs value in A & B are completely different while the Centre C machine has MA instead of mAs values were different.

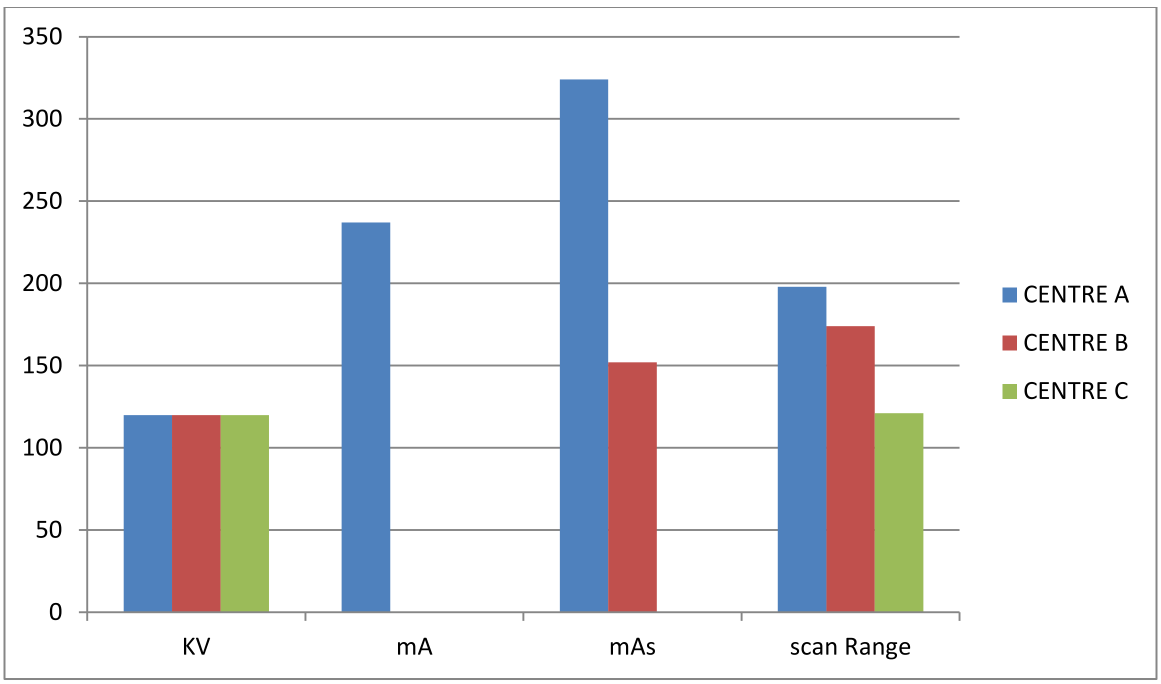

Fig 4.1: Comparison of Head CT scan parameters between the Study Centres

The bar chart in Fig 4.1 showed the main kV values for head CT in Centre A, B & C are the same. The Chest CT has different kV values in both the centers (A, B & C) but there is no available data for chest CT in Centre B during the study period, in the abdomen, Center A & C have the same value while that of centre B is different.

The mean mAs value in A & B are completely different while the Centre C machine has MA instead of mAs values were different.

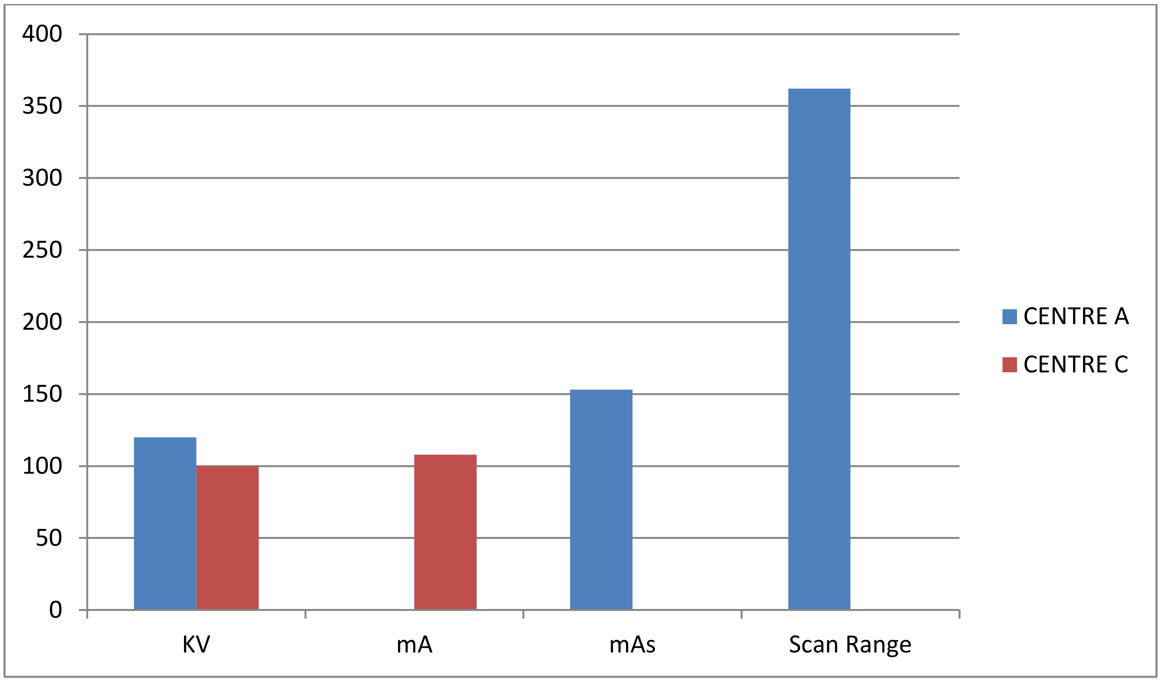

Fig 4.2: Comparison of Chest CT scan parameters between the Study Centres

The bar chat in Fig 4.2 showed the main kV values for Chest CT in center A is higher than that of centre C while centre B the values were not recorded. Whereas for the mAs, centre A also has the highest compared to centre C. While for the scan range centre A still has the highest scan range.

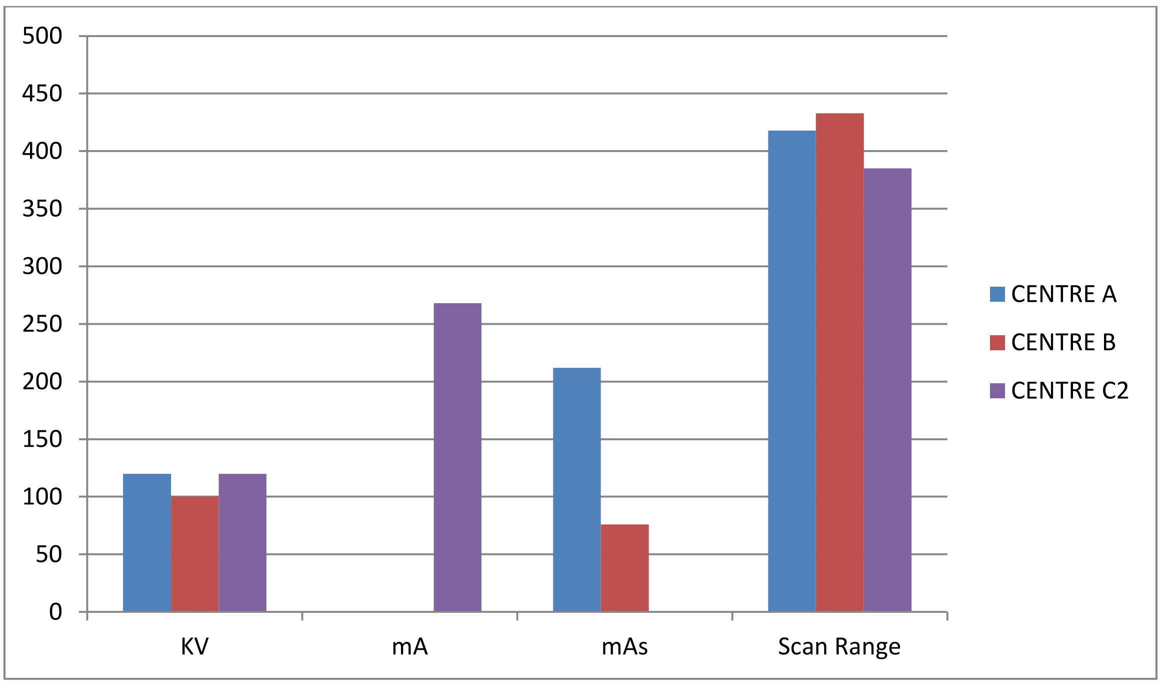

Fig 4.3: Comparison of Abdominal CT scan parameters between the Study Centres

The bar chat in Fig 4.3 showed the main kV values for Abdominal CT in center A is the same with that of centre B and is the highest compared to centre B. Whereas for the mAs, centre C has the highest mA followed by centre A and centre B has the lowest. While for the scan range centre B has the highest scan range.

4.4 Measured CTDI and DLP from the Study Center

The summary statistics for the measured dose parameters such as CTDI and DLP with their mean, standard deviation and 75^{th} percentile is present in Table 4.6. The 70^{th} percentile value was described as third (3^{rd}) quartile value for establishing the diagnostic reference level (DRLs).

Table 4.6: Measured CTD/W (mGy) and DLP (mGy*cm) Values from the study Centre.

Centre Region	GDI (mGy) Mean ±SD	DLP (mGy*cm) Mean ±SD	75^{th} Percentile (Third)
CENTRE A			
Head	52.5±96	1098.0±475.12	60.9 1275.6
Chest	10.8±0.87	431.0±91.96	10.0 453
Abdomen	15.1±0.60	689.6±43.98	15.5 726.5
CENTRE B			
Head	49.8±0	1003.1±77.37	49.8 1062.9
Chest	NA±	NA	NA
Abdomen	7.3±4.67	356.7±248.15	7.3 393.6
CENTRE C			
Head	43.7±3.59	820.1±173.32	44.3
Chest	10.7±2.58	442.6±139.81	11.3 446.6
Abdomen	11.7±3.95	491.7±134.77	11.6 459.7

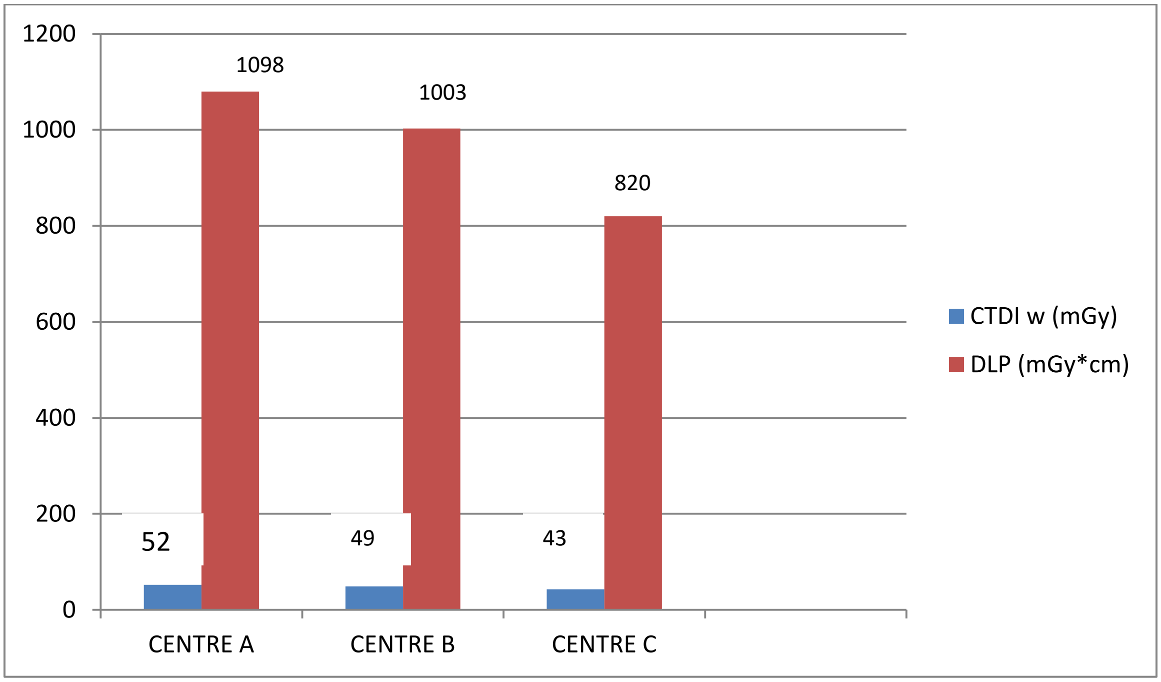

Fig 4.4: Measured head CTDIw (mGy) and DLP (mGy*cm) from the study centres.

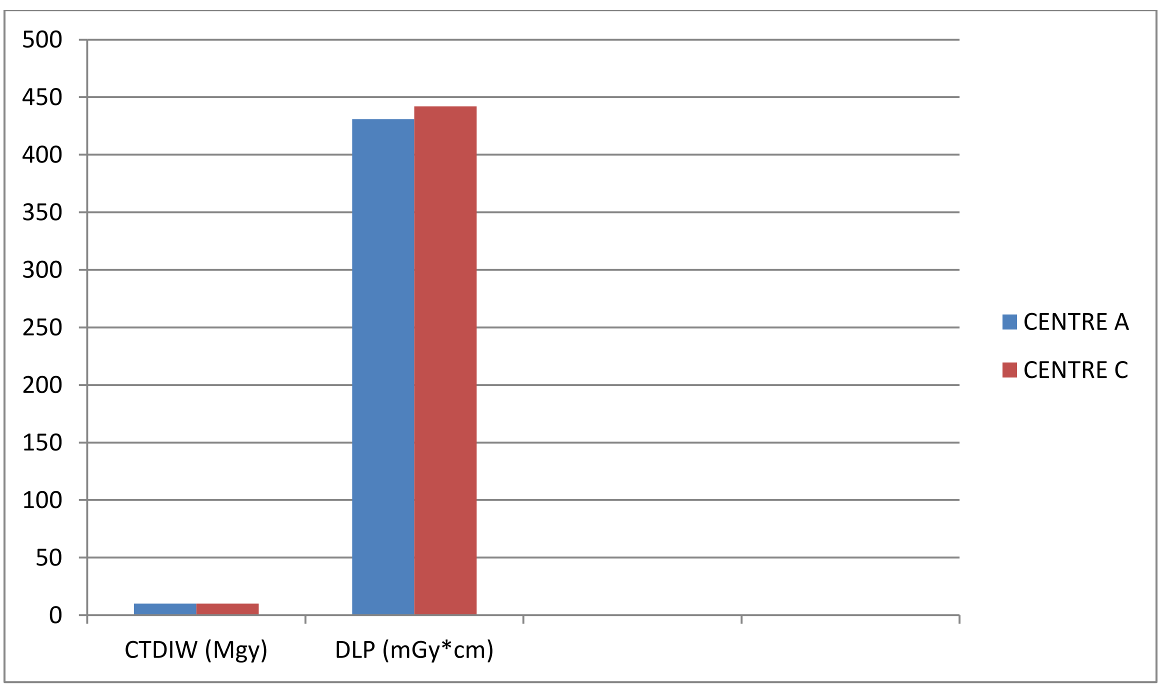

Fig 4.5: Measured Chest CTDIw (mGy) and DLP (mGy*cm) from the study centres.

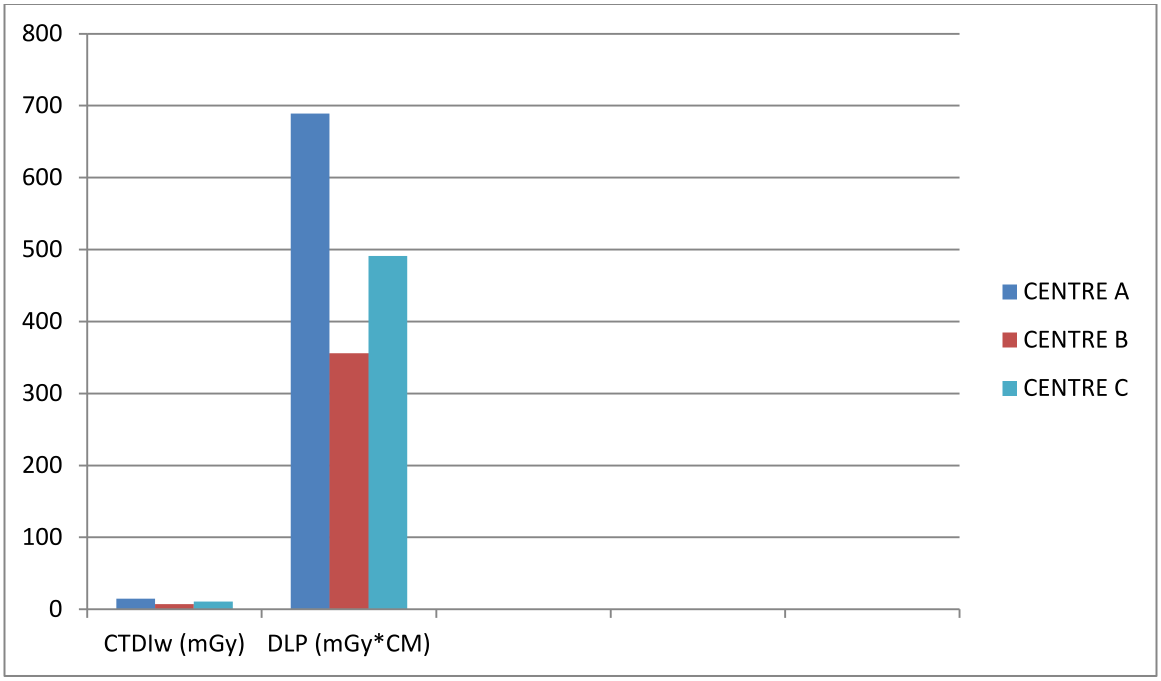

Fig 4.6: Measured Abdomen CTDIw (mGy) and DLP (mGy*cm) from the study centres.

From the result obtained above, Brain CT at centre (A) has the higher CTDIw, value followed by centre (B) and (C) with values of 52 mGy, 49 mGy and 43mGy respectively. Mean while, the highest DLP values were noted at centre (A) then Centre (B) and (C) as 1089mGY*cm, 100mGy*cm and 820 Gy*cm respectively.

For the chest CT, centre (A) and (C) almost have the same CTDIw values as 10mGy and 11.3mGy but the DLP in centre (C) was slightly higher than centre (A) with values of 431 mGy*cm and 442 mGy*cm respectively, centre (B) has no available data for both CTDIw and DLP values during the study period.

In abdominal CT, Centre (A) has higher CTDIw value, follows by centre (C) then centre (B) with 15MGy, 11mGy and 7MGy respectively. Then Centre (A) happened to be highest in terms of DLP values followed by centre (C) and (B) with 689 mGy*cm and 356 mGy*cm respectively.

The reason for high CTDIw and DLP values in centre (A) is because of the high kV and mAs used during the CT procedure. And the scan parameters and the protocol used were the main contributors to this higher output particularly, the tube current and the tube potentials.

4.5 Analysis of Establishing Diagnosis Reference Level (DRLs)

To establish DRLs, only routine procedure ought to have been included (Garba, 2014).

Analysis of the observed dose in CTDIw and DLP for head, chest and abdomen CT acquired with scanning mode was carried out.

Mean and third quartile values of the measured doses in CTDIw and DLP are shown in Table (4.7). A bar chart of third quartiles absorbed dose in CTDIw and DLP for brain, chest and Abdomen CT across all centres .

Table 4.7: Measured CTDIw (mGy) and DLP (mGy*cm) with 75th percentile values

Region	**CTDI Mean ± SD**		**DLP Mean ± SD**	**75%**
Head	48.7	±3.91	973.7±295.6	49.8 963
Chest	10.8	±1.8	435.6±113.6	10.9 432.8
Abdomen	11.0	±3.6	500.9±173.5	12.7 560

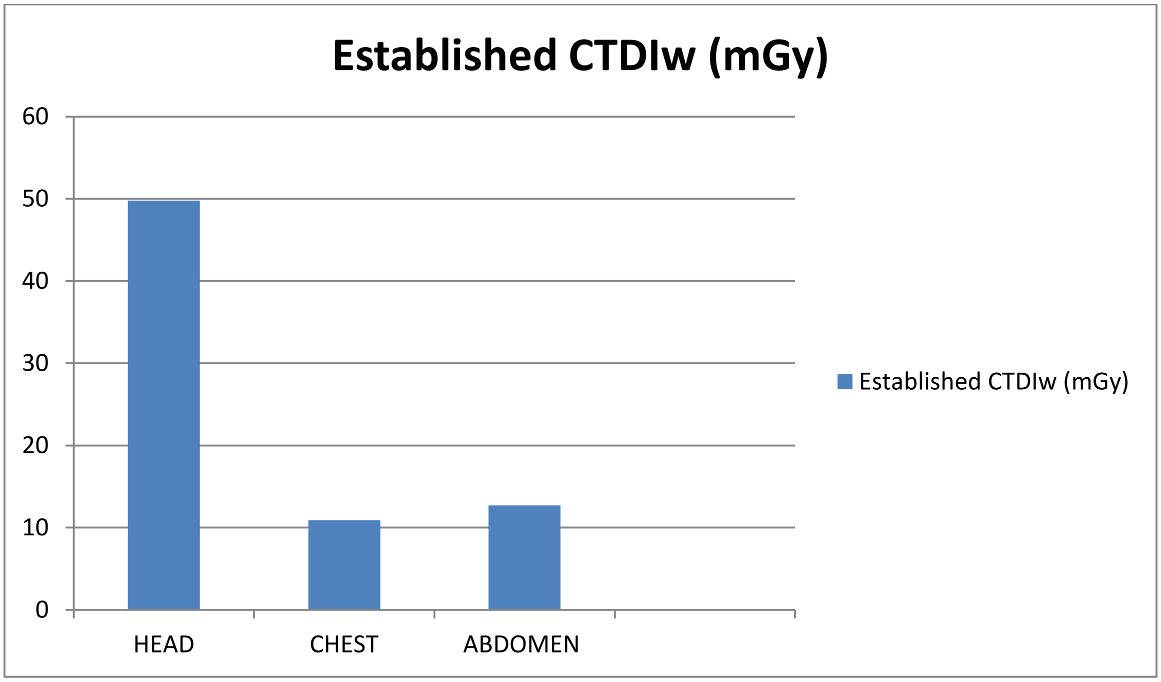

Fig 4.7: Established DRLs in terms of CTDIw(mGy) values.

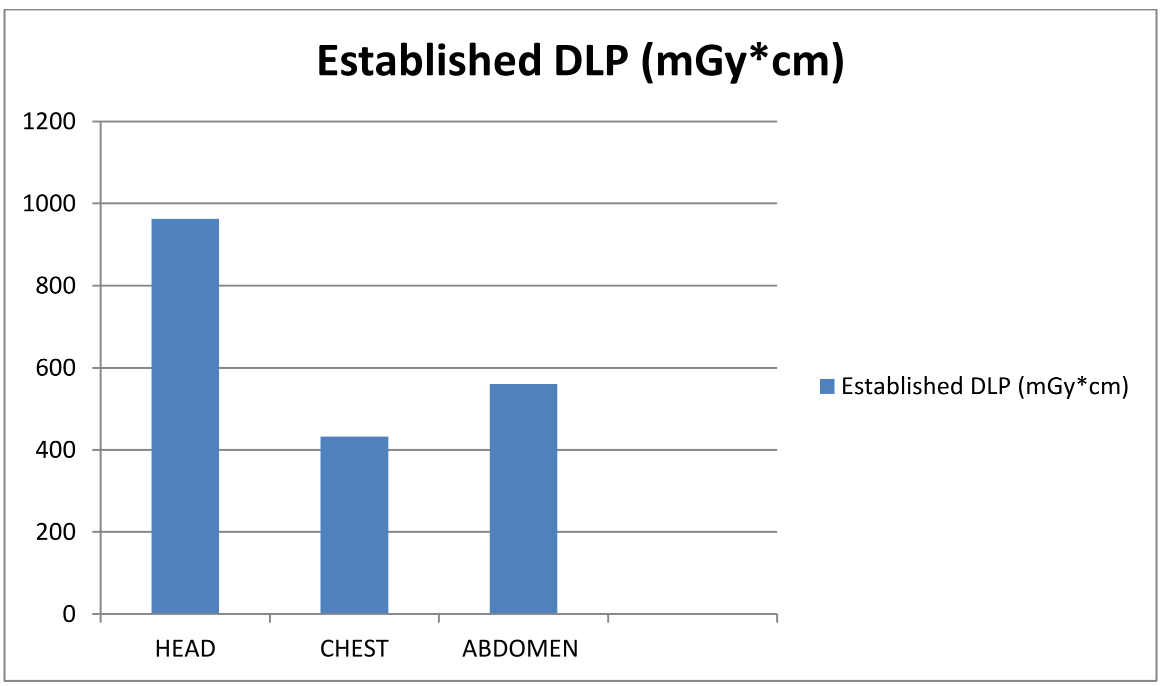

Fig 4.8: Established DRLs in terms of DLP(mGy*cm) values.

4.6 Comparison of DRLs in terms of CTDI with the International

The comparison of the new DRLs obtained with the established reference levels from the European countries as well as other countries is presented from tables 4.8 and 4.9. This would determine the possibility of radiation dose variance between the CT scanners and show the causes of that radiation dose variation in CT procedures.

Table 4.8: Comparison of DRLs in terms of CTDIw(mGy) with the international values

Region	**This study 2017**	**European commission**	**Portugal**	**Australia**
Author		European Union, 2014	Santos *et al.*, 2014	Arpansa, 2013
Head	49.8	10	75	47
Chest	10.9	10	14	9.5
Abdomen	12.7	35	18	10.9

Table 4.9: Comparison of DLP in terms of CTDIw (mGy) with the international values

Region	**This study 2017**	**European commission**	**Portugal**	**Australia**
Author		European Union, 2014	Santos *et al.* 2014,	Arpansa, 2013
Head	963	1000	1010	527
Chest	432.8	600	470	447
Abdomen	560	800	800	696

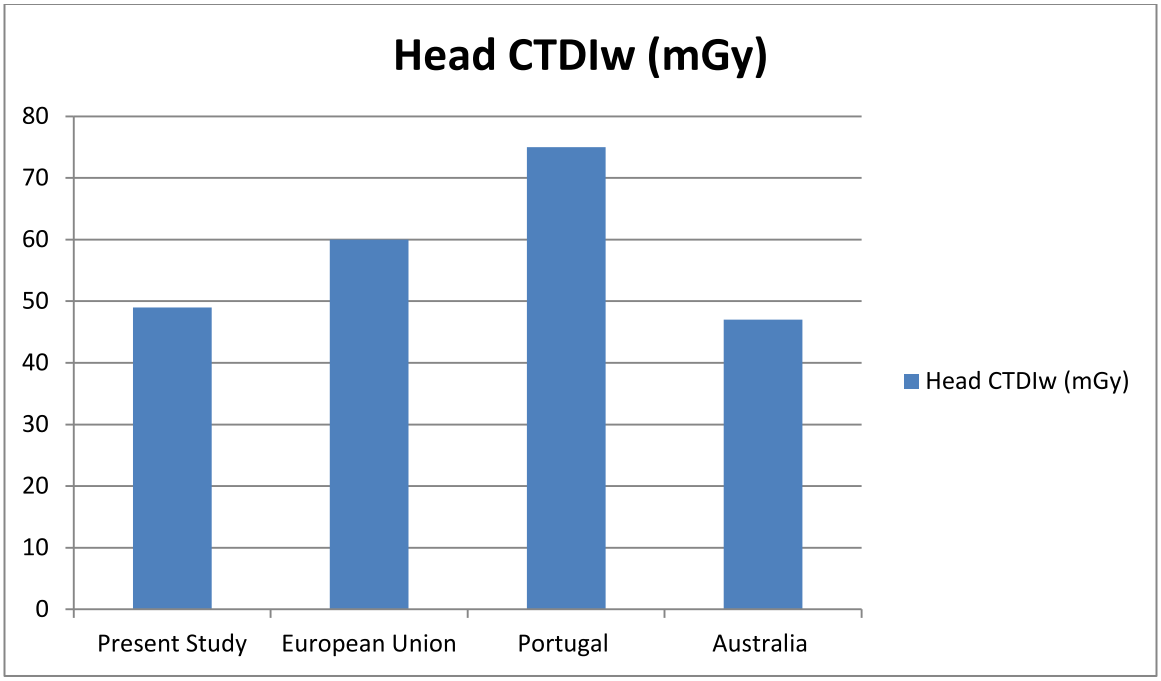

Fig 4.9: Comparison of head DRLs in terms of CTDIw (mGy) with internationals values

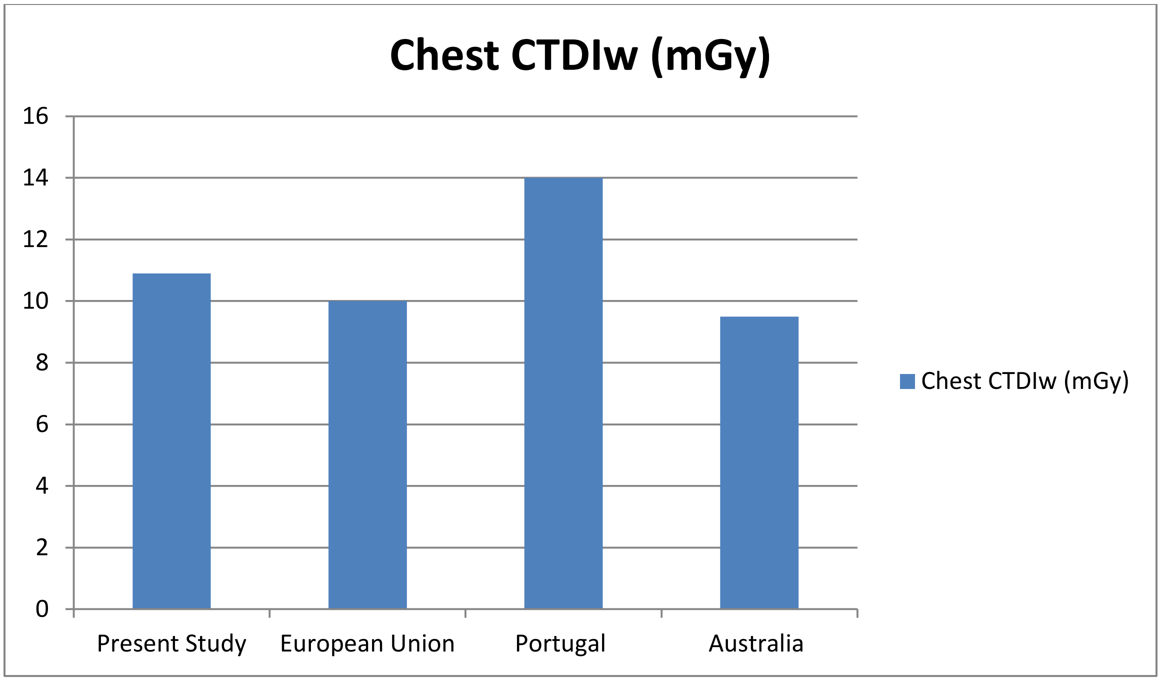

Fig 4.10: Comparison of Chest DRLs in terms of CTDIw (mGy) with internationals values

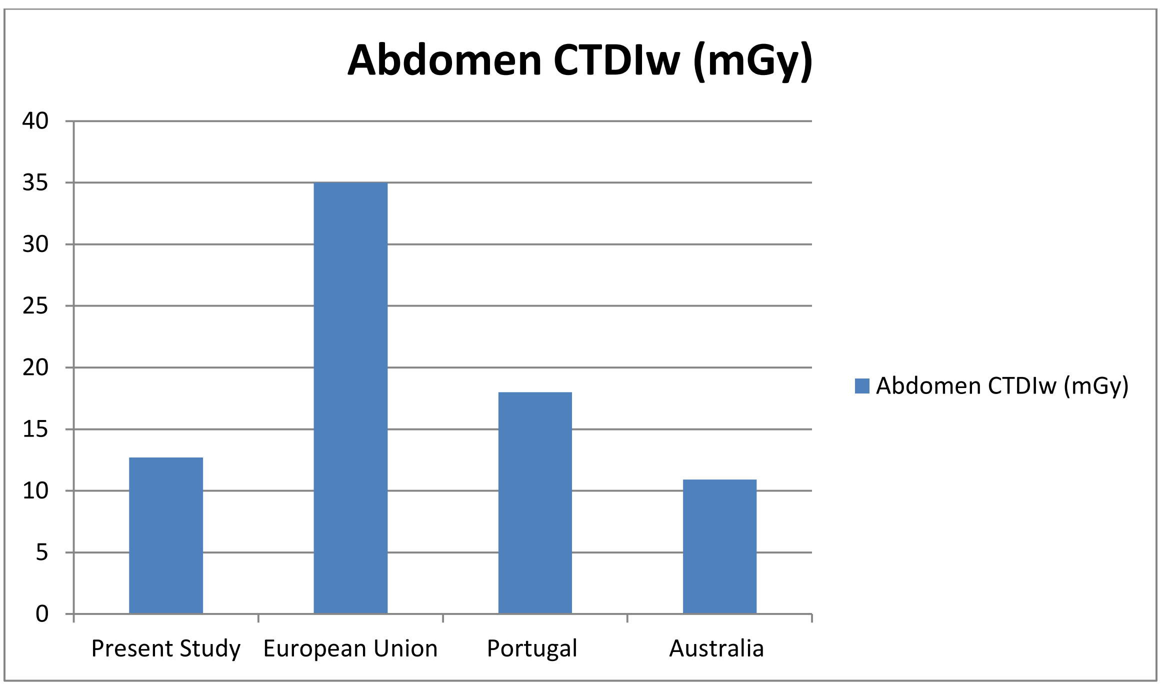

Fig 4.11: Comparison of Abdomen DRLs in terms of CTDIw (mGy) with internationals values

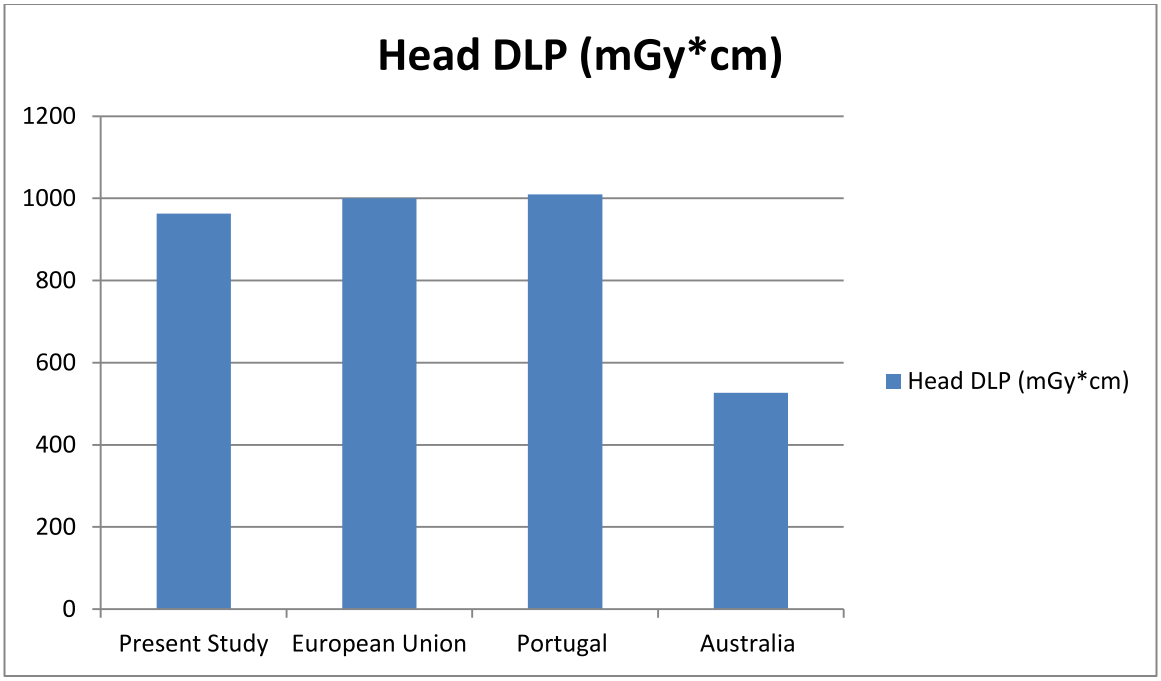

Fig 4.12: Comparison of head DRLs in terms of DLP (mGy*cm) with internationals values

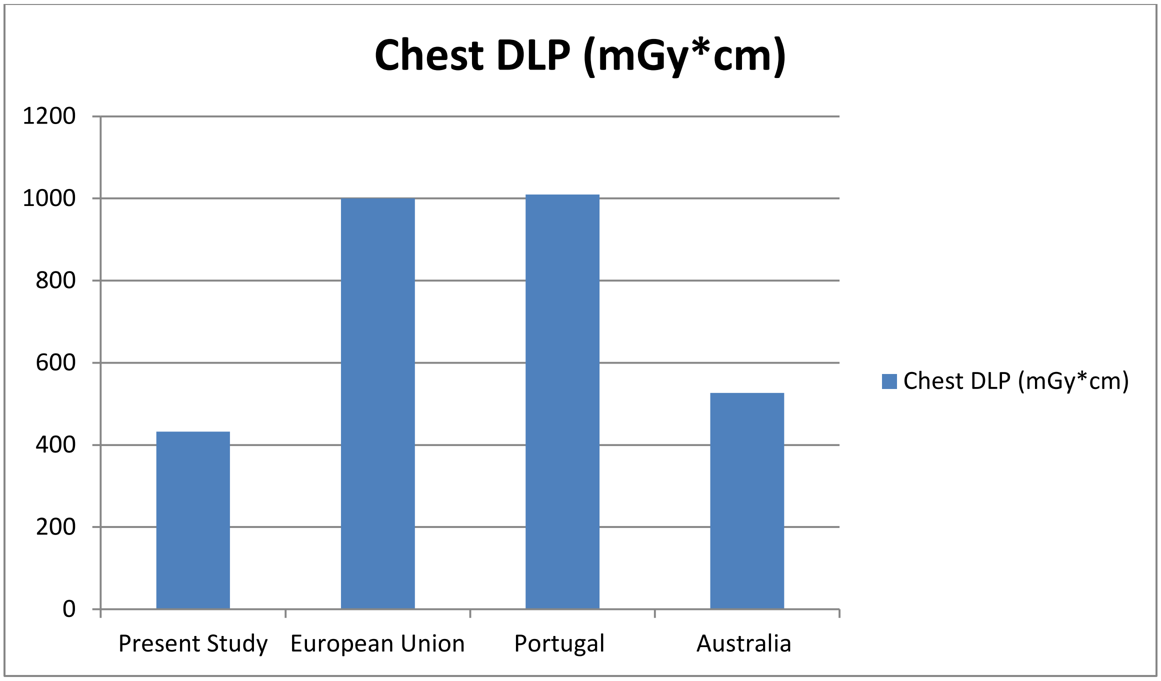

Fig 4.13: Comparison of Chest DRLs in terms of DLP (mGy*cm) with internationals values

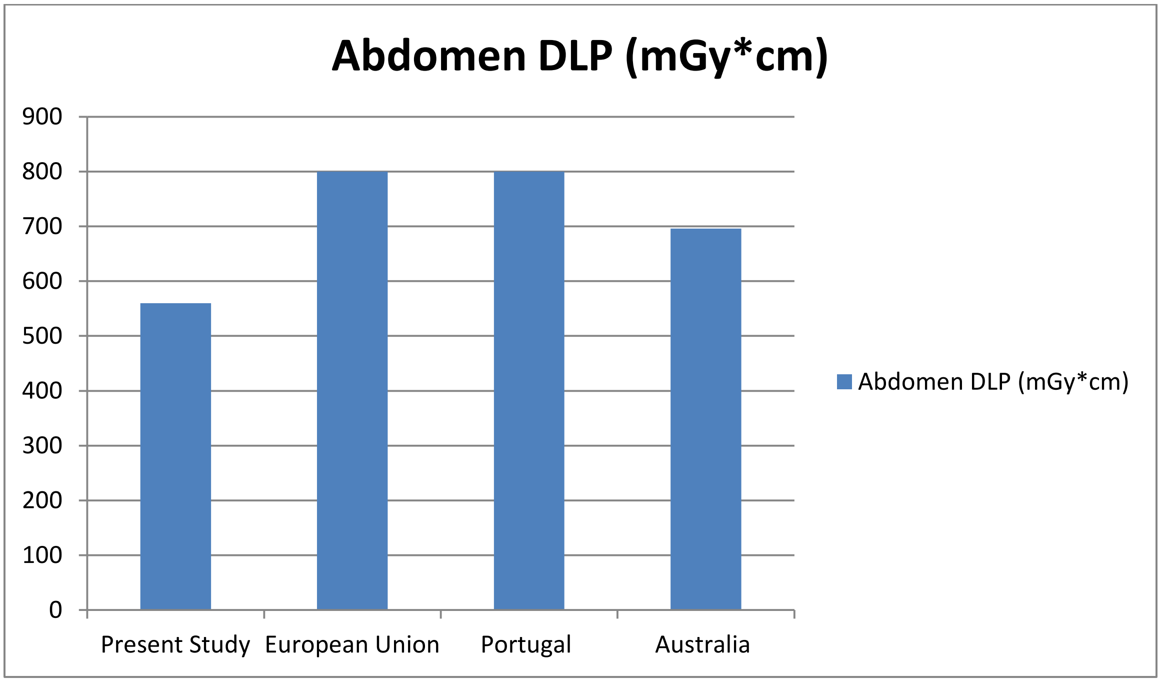

Fig 4.14: Comparison of Abdomen DRLs in terms of DLP (mGy*cm) with internationals values

4.7 Discussion

This study determined the CTDIw and DLP for adult patients undergoing routine, brain chest and abdominal CT scan in three Different Hospitals in Nigerian, one located in Keffi, Nasarawa State while the other two are located in Abuja Federal Capital territory (FCT). Potential Local diagnostic reference levels were established. Moreover factors, responsible for CTDIw and DLP variation between scanners are investigated and discussed in this chapter.

The international commission on Radiological Protection (ICRP) and European Union Directives adopted a concept known as Diagnostic reference level (DRL) in order to investigate incidences where patient dose during a radiological investigation is usually high and in urgent need of reduction (Garba, 2014).

The DRLs help to avoid excessive radiation dose to patients and population and that does not contribute to the clinical purpose of medical imaging tac. As such, in recent years it has become an important entity in the management of radiation doses delivered to the patient in diagnostic and interventional radiology. International, regional and national bodies have shown a keen interest in DRLs (Garba, 2014).

Scan Parameters

Previous studies have reported different dose value in CT imaging due to the variations in applied scan protocols and this limits comparison between studies (Garba, 2014). The findings of the present study also showed that the use of different scan parameters namely kV, mA, mAs, scanning range, pitch and scan time, being employed at different centers (Table 4.5), result in different CTDI and DLP values for the same procedure (Table 4.5).

Measured Scan Parameters

The measured CTDIw and DLP value for all the centers in this study were found to be different (table 4.6 and comparably the head CTDIw value is slightly higher in center (A) and lower in centre (B) and (C) but also lower compared to the values reported in Europe (Karim *et al.,* 2016).

For chest CT, the CTDIw values were the same from centre (A) and (C) were also the scan with the value reported from European (Karim *et al.*, 2016). The CTDIw values of abdomen were found to be lower in all centers than the reported values from European (Karim *et al.,* 2016).

Measured DLP values for all the centers in this study were also found to be different (Table 4.6) and by comparison the DLP values for head is higher at centre (A), (B) and (C) and they were all higher than the values reported in the Europe (European Commission, 2014). The chst DLP values were lower than the reported values in Europe likewise, abdomen shows lover DLP values in center (A), (B) and (C) respectively.

Compare to the reported values in the Europe (European Commission, 2014). This is because of the different scan parameters employed at each center, and the fact that, the dose optimization strategies were not being observed. Moreover, the scan parameters (exposure factors) are almost the same for adults, head, chest and abdominal CT a particular center.

Irrespective of the patient characteristics (age and weight) of the adult protocol does not change. Moreover, it has also been observed that setting of scan parameters such as the mA, mAs, kV, tube rotation time, pitch collimation and scanning range is a major contributor to the patient dose received during a CT scan procedure (Garba, 2014).

Diagnostic Reference Level (DRLs)

It has been recommended that the DRLs should be set at the level of the third quartile in the dose distribution of the measured CTDIw per series and DLP per examination. The third quartile value is chosen as an appropriate investigation level on the grounds that if 75% of the CT units can operate satisfactory below this dose level, then the remaining 25% should be made aware of their considerably.

Less than optimal performance operators of units should be encouraged to adjust their radiographic protocols by lowering the kV, mA and mAs or increasing the slice thickness to bring their dose in line with 75% majority (Ali, 2005; Garba, 2014). DRLs should be established using routine examinations (European Commission, 1999).

Therefore, this study considered only those scans dose on axial and helical mode as this is the routine protocol at the study site.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

During the course of this radiation dose assessment, I was privileged to carry out this study in three different hospitals in Nigeria, namely' National Hospital Abuja, Garki Hospital and Federal Medical Centre Keffi, Nasarawa State, Nigeria. A total number of 131 data of patients were collected across the three study centers. The data were collected from the computed system archived where the exposure parameters are stored at the control console of the study centers.

The data collected were analyses statistically. Local diagnostic reference level was established for brain, chest and abdomen as (49.8mGy and 96mGy*cm, 10.9mGy and 432.8mGy*cm and 12.7mGy and 560mGy*cm) for CTDIw and DLP respectively. The results were compared with the world wide limits for radiological interpretation.

5.2 Conclusion

Diagnostic reference levels were primarily introduced to avoid situations of high patient absorbed radiation dose (Garba, 2014). Furthermore, the CTDI's and DRL's should not be exceeded when departments operate under normal diagnostic and technical practices (ICRP, 1991). The aim of this study was to establish a Local Diagnostic Reference Level for routine head, chest and abdomen CT scan in three Nigerian hospitals for the purpose of dose optimization.

The CTDI and DLP evaluation was done following EC guidelines. However, variation of CTDIw and DLP for the same procedure was observed from one centre to another. This is due to the application of different scan protocols at each of the centres. The reason the

CTDIw with higher than in other studies is due to a high tube current and tube current-time product being employed. However, the CTDI and the DLP in most of the study centres are within or below the values in the European Commission Report.

5.3 Recommendations

Although the CTDIw obtained is relatively similar to the reported data in the literature, and the DLP values is comparably higher than all of the reported data as compared with published results from other countries, these are the recommended initial Local Diagnostic Reference Levels (LDRLs) for three centers. Also, variation between CT scan centers was noted.

1. It is therefore recommended that the tube current and tube current-time product be investigated and reduced where possible in order to reduce the absorbed radiation dose.
2. the protocol for head, chest and abdomen CT is harmonized across all CT centers in Nigeria.
3. The final recommendation is that an audit should be conducted in two (2) or more years' time to establish revised LDRLs that should be conducted in two (2) years' time to establish revised LDRLs that should be equal or similar to the internationally established DRLs.
4. A need for means to assess image quality in CT was seen, in order to measure the performance of the CT scanners in an objective way.
5. Simpler method for local assessment of image quality and dose might also contribute to the optimization of examination practices.

5.4 Limitation of the Study

Only adult patient that come for routine head, chest, abdominal CT examinations and weighed 70±3 kg were included in the study.

REFERENCES

AAPM (2008). *The Measurement, Reporting and Management of Radiation Dose in CT*. American Association of Physicist in Medicine Report. PP-23

AAPMR (2008). *Measurement, Reporting and Management of Radiation Dose in CT produced by task group 23*. American Association of Physicist in Medicine Report No 96. Available at: http//www.aapm/pubs/reports/rpt 96.

Abdulkadir M.K., Cyril S. and Francis H., (2016). *Determination of Computed Tomography Diagnostic Reference Levels in North-Central Nigeria*.

Abdullah A. (2009). *Establishing Dose Reference Level for CT Examination in Malaysia.* Thesis submitted in fulfillment of the requirements for the degree of Master of Science University Sains Malaysia. Available at: http://www.eprints.usm.my.

ACR (2012). *Computed Tomography Quality Control Manual.* Radiologic Technologists Section. Pp-10

Adams E.J., Brettle D.S., Jones A.P., Hounsell A.R. and Mott D.J., (1997). *Estimation of Fetal and Effective Dose for CT Examinations.* The British Journal of Radiology. Pp-34

Adeyekun A.A. and Obi-Egbedi-Ejakpovi E.B., (2013). *Computerised Tomographic Patterns in Patients with Head Injury at the University of Benin Teaching Hospital*. Nigerian Journal of Clinical Practice. Pp-16.

AJNR (2007). *Computerized Tomography.* American journal of Neuroradiology. Pp 27-31. Available at: http://www.ajnr.org

Ali M.H. (2005). *Trends in CT abdominal doses in Malaysian Practices.* Research thesis submitted as part of the requirements for the award of the degree of doctor of health. University Sains Malaysia. Pp 45.

Aroua A., Samara E., Bochud F.O., Meuli R. and Verdun F.R. (2013). *Exposure of the Swiss Population to Computed Tomography.* BMC Medical Imaging. Pp-13-22. Available at: http://www.biomedcentral.c3eom.

Aweda M.A. and Arogundade R.A. (2007). *Patient Dose Reduction Methods in CT Procedures.* International Journal of Physics Sciences. Pp-13.

Barnes E. (2010). *CT Doses, Widely Variable in Europe, are Reduced by Staff Efforts.* Paper Presented at the European Congress of Radiology (ECR). Available at: http://www.auntminnie.com/ staff.

Barry F.W. (2001). *Diagnostic Reference Levels: The way forward.* The British Journal of Radiology. Pp-34.

Bongartz G., Golding SJ., Jurik A., Leonardi M., Van Meerten EP., Geleijns J. (1999). *European guidelines on quality criteria for computed tomography (EUR 16262 EN).* Luxembourg: European Commission. Pp-17.

Bourguignon M.H. (2009). *Medical Application of diagnostic reference levels in medical practice.* Refresher Course 7

Brandberg J., Lonn L., Bergelin E., Sostrom L., Forssell-Aronsson E. and Starck G. (2008). *Accurate Tissue Area Measurement with Considerably Reduced Radiation Dose Achieved by Patient-specific CT Scan Parameters.* The British Journal of Radiology 81. Pp-801-808.

Breiki G., Abbas Y., El-ashry M. & Diyab H. (2008). *Evaluation of Radiation Dose and Image Quality for Patients Undergoing CT Examination.* IX Radiation Physics and Protection Conference, 15-19 November, Nasr City-Cairo, Egypt. Available at: http://www.rphysp.com/contents.

Brenner D.J. and Hall E.J. (2007). *Computed tomography an increasing source of radiation exposure.* The New England Journal of Medicine, 357(22). Pp-2277-2284. available at:http://doi.org/l

Bushong S.C. (2008). *Radiological Science for Technologists: Physics, Biology and Protection*. 9th ed. Missouri: Westline Industrial Drive St. Louis. Pp-223

Buzug T.M. (2008). *Computed Tomography: from Photon Statistics to Modern Cone-Beam CT*. Berlin Germany: Springer-Verlag Heildelberg. Pp-421

Carlton R.R. and Adler A.M. (2013). *Radiographic Imaging Concepts and Principles*. 5thed. Clifton Park, New York: Delmar, Cengage Learning. Pp-28

Carter C.E. and Veal B.L. (2008). *Digital Radiography and PACS*. Philadelphia, (PA)USA: Mosby Elsevier. Pp 198-199.

Chougule A. (2005). *Reference Doses in Radiological Imaging.* Poland Journal of Medical Physic Engineering. Pp-34

CUC (1999): *European guidelines on quality criteria for computed tomography.* Commission of the European Communities EUR 1262. Luxemburg, Belgium: Office for Official Publications of the European Communities.

Cunningham I.A. and Judy P.F. (2000). *Computed Tomography*."*The Biomedical Engineering Handbook:* 2nd ed. Bronzino, J.D. (ed.). Boca Raton: CRC Press. Available at: http://www.kemt.fei.tuke.sk

DAA (2013). *Precision in Recording and Reporting Data.* Data Analysis Australia. Available at: http://www.daa.com.au/analytical-ideas/recording-and-reporting-data.

Dogo D., Yawa T., Hassan A.W. and Tahir B. (2000). *Pattern of Abdominal Trauma in North Eastern Nigeria.*

Dose Reduction in CT of the Head and Neck. The Internet Journal of Radiology. Pp-45

Drouet F. (2007). *The Diagnostic Reference Levels (DRLs) in Europe. Available* at: http://www.eu-alara..net.

Dzialowski I. and Kummer R.V. (2005). *Role of Diagnostic Radiology in the Management of Acute Stroke.* C2I2, Volume III, Issue 3. Available at:http://www.c2i2.org/vol_iii_issue_3/pdf/role_of_diagnostic_radiol.

EC (1996). *Guidelines on Quality Criteria for Diagnostic Radiographic Images.* European Commission EUR 16261EN. Available at: http://www.bookshop.europa.eu

ECR (2010). *Paper Presented at the European Congress of Radiology*. Available at: http://www.auntminnie.com/ staff writer .

Edmonds K.D. (2009). *Diagnostic Reference Levels as a Quality Assurance Tool.* The Radiographer. 56(3). Pp-32-37.

EG (2014). *Quality criteria for computed tomography.* Elameen.

Elameen S.E.A. (2010). *Techniques and Radiation Doses in CT Examinations of Adult Patients.* Master's thesis submitted to the department of Medical Physics, University of Maiduguri, Borno State.

Erondu O.F., Okoro C.R., Aniemeke J.I. and Ugwu A.C. (2011). *Pattern of CT Referrals Among Physicians in the South-South Region of Nigeria.* American Journal of Scientific and Industrial Research. Pp-30

European Commission (2014).Radiation protection 109: Guidance on diagnostic reference levels for medical exposure. office for official publications of the European community, on Euro web server: http://europa.eu.int Management of Acute Stroke, C2I2, Volume III, Issue 3. Available at: Master's thesis submitted to the department of Medical Physics, University of Sudan.

Files T.P.A., Brennen S.I., Scott S.A. and Davies J.H. (2001). *A survey of patient dose and image quality for computed tomography scanners in Wales.* Pakistan Journal of Medical Science. Pp-34.

Foley S.J., McEntee M.F. and Rainford L.A. (2012). *Establishment of CT diagnostic reference levels in Ireland.* The British Journal of Radiology. Available:at:http://doi.org/l0.1259/bjrI.

Garba I. (20I4). *Computed Tomography dose index for head CT in Northern Nigeria*.

Gelejant Lewis MA. Edyvean S. Sassi SA, Kiremidjian H, Keat N, Britten AJ (1999). Estimating patient dose on current CT scanners: Results of the Impact CT dose survey. London).

GEMS (2001). *Dose in Computed Tomography Basics, Challenges, and Solutions.* Technical Report. 71113-BE France. Available at: http://www.gemedicalsytemseurope.com.

GM (2013). Map of Nigeria. Google Map. Available at: http://www.maps.google.com.

Goldman L.W. (2007). *Principles of CT: Radiation Dose and Image Quality.* Journal of Nuclear Medicine Technology. Pp-54

Google Map (2015). Map of Kano State. Available at http://www.maps.google.com.

Graham H. and Frances A. (1992). *Medical Physics for Advanced Level*. Simon and Schuster Education Campus 400, Maylands Avenue Hemel Hempstead Herts.

Grant K. and Schmidt B. (2011). *Automated Dose-Optimized Selection of X-ray Tube Voltage.* CARE kV. Available at: http://www.usa.siemens.com/healthcare.

Gray J.E., Archer B.R., Hobbs B.B., Mettler F.A., Pizzutiello R.J., Schueler B.A., Strauss K.J., Suleiman O.H. and Yaffe M.J. (2005). *Reference Values for Diagnostic Radiology.* Application and Impact, Radiology. 235. Pp-354-358.

Hart D, Jones DG. Wall BF. (2002). *Estimation of effective dose in diagnostic radiology from entrance surface dose and dose area product measurements.*

Hart D. Wall B.F. (2002). *Radiation exposure of the UK population from medical and dental X-ray examinations (NRPB-W4).* Chilton: National Radiological Protection Board.

Hidjat N., Wolf M., Nunnemann A., Liersch P., Gebauer B. and Schro R.J. (1999). *Medical Physics Survey of conventional and Spiral CT doses*. 1 index terms. Pp-395-401.

Holubinka M.R., Jones A.P., Rawlings D.J., Roberts P.J., Robertson J., Wall B.F. (1992). *National protocol for patient dose measurements in diagnostic radiology*. Chilton: National Radiological Protection Board.

Huang Y.H., Wu T.H., Su C.T., Chen M.C., Hung J.J. and Lee J.S. (2004). *Absorbed Dose Evaluation to Patients Undergoing PT-CT and Conventional CT Examination.*

IAEA (2007). *Dosimetry in Diagnostic Radiology an International Code of Practice.* Technical Reports Series No.457 International Atomic Energy Agency vailable at.www.pub.iaea.org.

IAEA (2009). *Dose Reduction in CT while Maintaining Diagnostic Confidence*. A feasibility/demonstration study, Radiation Safety and Monitoring Section.

IAEA (2011). *Radiation Protection and Safety of Radiation Source*. International Basic Safety Standards. General Safety Requirements Part 3 No. GSR Part 3 (Interim).

Ibrahim U. (2015). *Lecture Note on Radiation Protection.* Nasarawa State University, Keffi, Nigeria. Unpublished.

ICRP (1991). *Radiological Protection.* Recommendations of the International Commission on Radiological Protection. Available at: http://www-pub.iaea.org/pI53interim. Publication 60, 1990 Annals, 21: pp-1-3.

ICRP (1996). *Radiological Protection.* Publication 60. 1990 Recommendations of the International Commission on Radiological Protection. Annal. Index.

ICRP (20007). *Radiological Protection.* Publication 60. 1990 Recommendations of the International Commission on Radiological Protection. Annal. Index.

IEC (1999). *Medical electrical equipment. Part 2: particular requirements for the safety of X-ray equipment for computed tomography.* International Electrotechnical Commission. Geneva. Switzerland. Pp-44.

IPRA (2013). *Evaluation of CT Dose and Image Quality in three States of Brazil.* Proceedings of third European Ionzing Particle Ragulatory Agency Congress, June 14-18, Helsinki, Finland.

Jones D.G., Shrimpton P.C. (1991). *Normalised organ doses for X-ray computed tomography calculated using Monte Carlo techniques*. Chilton: National.

Kalra M.K., Maher M.M., Toth T.L., Hamberg L.M., Blake M.A., Shepard J. & Saini S. (2004). *Strategies for CT Radiation Dose Optimization.* Radiology. Pp-619-628.

Karabulut N. and Ariyurek M. (2006). *Low dose CT: Practices and Strategies of Radiologists in university hospitals.* Diagnostic Interventional Radiology. Pp-3-8.

Karim M.K.A., Hashim S., Sabarudin A., Bradley D.A. and Bahruddin N.A. (2016). *Evaluating organ dose and radiation risk of routine CT examinations in Johor, Malaysia.* Available at: http://www.eprints.usm.my

Karthikeyan D. and Chegu D. (2005). *Step by Step CT Scan (A practical guide for Residents and Technologist).* New Delhi, India: Jaypee Brothers Medical Publisher. Pp-32.

Koller C.J., Eatough J.P. and Bettridge A. (2003). *Variations in Radiation Dose Between the Same Model of Multislice CT Scanner at Different Hospitals.* The British Journal of Radiology. Pp-798–802.

Lewis M. (2005). *Radiation Dose Issues in Multi-slice CT Scanning.* Impact technology update no. 3. Available at: http://www.impactscan.org/msctdose.htm [3/4/2010].

Lewis M.A., Edyvean S., Sassi S.A., Kiremidjian H., Keat N., Britten A.J., (1999). *Estimating patient dose on current CT scanners*. Results of the Impact CT dose survey. London.

Ling (2009). *Factors Affecting Image Quality and Radiation Dose in MDCT.* Available at: http//www.gehealthcare.com.

Liu H., Zhuo W., Chen B., Yi Y. and Li D. (2008). *Patient Doses in Different Projections of Conventional Diagnostic X-ray Examinations.* Radiation Protection Dissymmetry. Pp-334-338.

Livingstone R.S., Eapen A., Dip N.B. and Hubert N. (2006). *Achieving Reduced Radiation Doses for CT Examination of the Brain Using Optimal Exposure Parameters.*

Luxembourg (2001). *Guidance on diagnostic reference levels for medical exposure.* Office for Official Publications of the European community. Radiation protection 109. on Euro web server: http://europa.eu.int Management of Acute Stroke, C2I2, Volume III, Issue 3. Pp-43.

Mayo J.R., Aldrich J. and Müller N.L. (2003). *Radiation Exposure at Chest CT*. A Statement of the Fleischner Society. Journal of Radiology. Pp-15–21.

McEntee M.F. and Rainford L.A. (2012). *Establishment of CT diagnostic reference levels in Ireland.* The British Journal of Radiology. Available:at:http://doi.org/l0.1259/bjrI.

Michel H.B. (2008). *Diagnostic Reference Levels in Medical Practice.* Paper presented at Ionzing Particle Ragulatory Agency 12 Congress at Buenos October 22.

Morin R.L., Gerber T.E. and McCollough C.H. (2003). *Radiation Dose in Computed Tomography of the Heart*. Circulation. Pp-917-922. Available at:http://www.circ.ahajournals.org/cgilcontent/fuI1/1

Mozumdar B.C. (2003). *The Control of Radiation Exposure from CT Scans*. The Internet Journal of Radiology. Pp-54

Mulkens T., Salgado R. and Bellinck P. (2007). *Dose Optimization and Reduction in CT of the Head and Neck, Including Brain.* The Internet Journal of Radiology. Pp-59

Mundi (2013). *Nigeria Demographics Profile.* Available at: Indian Journal of Radiology Imaging.

Mundi A., Hammed S., Dlama J., Abdul A., Peter E., ltopa R. and Goriya K. (2015).

Munro L. (2004). *Basic Radiation Protection for Everyday Use How to Achieve ALARA:* World Health Organisation. Geneva, Switzerland: 20 Avenue Appia. Available at: http://www.humaninfo.ro/gsdl.

Ngaile J.E. and Msaki P.K. (2006). *Estimation of Patient Organ Doses from CT Examinations in Tanzania.* Journal of Applied Clinical Medical Physics. Pp-80-94.

Ngaile J.I., Msaki P. and Kazema R. (2006). *Towards establishment of the national reference dose levels from CT examinations in Tanzania*.

Nosach Y. (2006). *CTDI and DLP Measurement in Estonian Computed Tomography Cabinets.* Master's thesis submitted to the institute of experimental Physics and Technology, Faculty of Physics and Chemistry University of Tartu. Available at: http://www.dspace.utlib.ee.

Nsoor N. (2009). *Factors that can be Attributable to Radiation among Paediatric Age Group Undergoing Brain Computed Tomography.* Pakistan Journal of Medical Science. Pp-34

Origgi D., Vigorito S. and Villa G. (2000). *Survey of CT technique LI.Y. I sai. C. J. Tung survey of CT scanners in Taiwan*. Dose descriptors, dose guidance levels, and effective doses. Pp-23.

Papadimitriou D., Perris A. (2000). *A survey of 14 CT scanners in Greece and 32 scanner in Itall)* Mosby Elsevier. Pp 198-199.

Punch K.F. (2006). *Developing Effective Research Proposal.* 2nd ed. London: Sage Publications Ltd.

Reddinger W.L. (1997). *CT Instrumentation and Physics.* Available at: http://www.eradiography. net/mrict/basic_CT.

Romans L. (2013). *Radiation dosimetry in CT.* Available at: http://www.CEwebsource.com.

Rothenberg L.N. and Pentlow K.S. (1992). *Radiation Dose in CT.* RadioGraphic.

RPB (1991). *Recommendations of the International Commission on Radiological Protection.* Radiological Protection Board. (ICRP 60). Oxford: Pergamon Press.

Rydberg J., Kenneth A.B., Karen S.C., Michael D.P., Dewey J.C. Jr., Alex M.A., Scott A.P. and Kenyon K.K. (2000). *Multisection CT: Scanning Techniques and Clinical Applications.* RadioGraphics. Pp-1787-1806.

S.E.A. (2010). *Techniques and Radiation Doses in CT Examinations of Adult Patients.*

Seabourn J.T. (2010). *Radiation Dose Considerations in CT Imaging.* Power Point Presentation. Available at: http://www.imirad.net/RADIATION.

Seeram C. (2009). *Physical Principles, Clinical Applications, and Quality Control*. 3rd Ed. Westline Industrial Drive St. Louis, Missouri: Sounders Elsevier.

Seifert H., Hagen T.H., Bartylla K. & Bla G. (1997). *Patients Doses from Standard and Spiral CT of the Head using a Fast Twin-beam System.* The British Journal of Radiology. Pp-1139-1145.

Shrimpton P.C., Hillier M.C., Lewis M.A. and Dunn M. (2006). *National Survey of Doses from CT in the UK 2003.* The British Journal of Radiology. Pp-43

Shrimpton PC., Hillier MC.M.S. and Godwin S. (2014). *Public Health England – Doses from Computed Tomography (CT) Examinations in the UK – 2011.* Review.

Shrimpton, PC, Hillier MC, M. S. and G. S. (2014). Public Health England - Dosesfrom Computed Tomography (CT) Examinations in the UK - 2011 Review.

Smith A., Shah G.A. and Kron T. (1998). *Variation of Patient Dose in Head CT.* The British Journal of Radiology. Pp-12

Smith A.B., Dillon W.P., Gould R. and Wintermark M. (2007). *Radiation Dose-Reduction Strategies for Neuroradiology CT Protocols*. American Journal of Neuroradiology. Pp-1628 –1632. Available at: http://www.ajnr.org.

Subbarao K., Banerjee S., Aggarwal S.K. and Bhargava S. (1997). *Diagnostic Radiology and Imaging.* I. New Delhi India: Jaypee Brothers Medical Publisher.

Tabari A.M. and Garba I. (2007). *Diagnostic Yield of Cranial Computed Tomography Scan in Kano, Nigeria.* Nigerian Journal of Basic and Clinical Sciences. Pp-22-25.

Tack D. and Gevenois P.A. (2010). *Radiation Dose from Adult and Paediatric Multidetector CT.* SpringerLink. Available at:http://www.springerlink.com/index [23/7/2010]

Tongco D.C. (2007). *Purposive Sampling as a Tool for Informant Selection.* A journal of Ethnobotany Research and Applications. Pp-147-158.

Toth T. (2006). *CT x-ray dose basics (not for the physicist).* Power Point slides from General Electric.

Treier R., Aroua A., Bochud F., Samara E., Verdun F.R., Stuessi A., Trueb Ph.R. and Zeller W. (2009). *Diagnostic Reference Levels in Computed Tomography in Switzerland.* IFMBE Proceedings 25/ III, pp. 146–149.

Tsapaki V., Kottou S. and Papadimitriou D. (2001). *Application of European University of California, Santa Cruz.* Environmental Health and Safety. Radiation Safety Fundamental Work Book. Available Canada.

URC (2003). *Reference doses and DRLs.* The background and the publication. In: Proceedings of UK Radiological Congress: Birmingham. London: British Institute of Radiology.

Van der Molen A. J., Schilham A., Stoop P., Prokop M., and Geleijns J. (2013). *A National Survey on Radiation Dose in CT in The Netherlands.* Insights into Imaging.

Wade J.P., Weyman J.E. and Goldstone K.E. (1997). *CT Standard Protocols are of Limited Value in Assessing Actual patient dose.* The British Journal of Radiology. Pp-1146-1151.

Wall B.F. (2000). *Implementation of diagnostic reference levels for x-ray examinations in the UK.* Wall National Radiological Protection Board, Chilton, Didcot, United Kingdom. Pp-462-465.

Wall B.F. and Hart D. (1997). *Revised Radiation Doses for Typical X-ray Examinations.* The British Journal of Radiology. Pp-437-439.

Walter H., Kent M.O. and Mohammad R.K. (2008). *Converting Dose Length Product to Effective Dose at CT*. The British Journal of Radiology. Pp-995-1003.

White M.J., Eatough J.P., Goldstone K.E. (1999). *Audit of effective dose for patients undergoing Xra computed tomography*. Cambridge: East Anglian Regional Radiation Protection Service.

Willis J. (2004). *Data Analysis and Presentation Skills.* An Introduction for the Life and Medical Sciences. West Sussex: John Wiley & Sons Ltd.

Wintermark M. (2008). *Radiation Dose Reduction Strategy for CT Protocols*. Successful Implementation in Neuroradiology Section. The British Journal of Radiology. Pp-499–506Available at: http://radiology.rsnajnls.org/cgi/content/full/2472071054.

Workman A., Kotre J., Shaw A., Fong R., Wall B., Bury R., (2000). *Diagnostic reference levels working party*. IPEM Newsletter.

Yates S.J., Pike L.C. and Goldstone K.E. (2004). *Effect of Multislice Scanners on Patient Dose from Routine CT Examinations in East Anglia.* The British Journal of Radiology. Pp-67

Yunusa G.H., Sadisu M., Ma'aji S.A., Saidu. A.M.B., Shamaki M.D. (2016). *Helical computerized tomography of the abdomen.* Indications and spectrum of findings in a tertiary health center.

Zarb F., McEntee M. and Rainford L. (2012). *Maltese CT Doses for Commonly Performed Examinations Demonstrate Alignment with Published DRLs Across Europe.* Radiation Protection Dosimetry. Pp-33.